Pedagogical Innovations in Mathematics Learning in Indonesian Elementary Schools:

A Systematic Literature Review and Future Research Directions

Abstract

Literature reviews about pedagogical innovations in mathematics learning in Indonesian elementary schools are of importance to determine further interventions for refinement and future research directions. This study aims at describing innovations of teaching and learning in mathematics and identifying the underlying problems by using a systematic literature review of scholarly articles published between 2014 and 2019. Additionally, the study outlines the development models used in these previous studies in order to propose a comprehensive future research agenda. The results of this study reveal that the majority of pedagogical innovations focus on developing learning materials and techniques. Elementary students in Indonesia have a negative perception towards mathematics subject, the teachers are less competent, and the learning resources are old-fashioned. The existing mathematics education research and development employs various prominent and recent development models. Its findings, unfortunately, have not been deeply discussed and widely disseminated in Indonesia. Therefore, it is of pivotal importance to consider more profound discussions and extensive dissemination of the findings in future endeavours.

**Keywords:** pedagogical innovations; mathematics learning; Indonesian elementary schools

Introduction

Literature reviews about pedagogical innovations in mathematics learning in Indonesian elementary schools are of importance to determine further interventions for refinement and future research directions. Conducting literature reviews is gaining more and more prominence to acquire the state-of-art knowledge on a particular topic in terms of creating research agendas, identifying gaps in research, or simply discussing a particular matter (Snyder, 2019). Thus, it is required for every single investigation to take literature reviews into account before running a study. Particularly in design research, it is pivotal to have an extensive literature review as preliminary research to gain evidence-based theoretical inputs leading to a better understanding of the problem, context, and relevant topics (McKenney & Reeves, 2018; Plomp, 2013). By doing so, it helps to make the design of the following interventions more suitable so that they address contextual problems more precisely.

The innovations of mathematics teaching and learning in Indonesian elementary schools, unfortunately, have not yet been clearly described so the room for improvement is large and upcoming study agendas are blurred. Furthermore, a systematic literature review of published scholarly articles is less popular among Indonesian scholars than a simple literature study from textbooks. Several recent literature studies that have been done merely conceptually discussed particular issues of mathematics learning. Just to name a few, Handayani et al. (2019) conducted a conceptual review of project-based learning with realistic mathematics education, Wulandari & Mariana (2018) explored mathematics concept in elementary schools based on traditional arts, and Hartono & Karnasih (2017) addressed the importance of mathematical modeling. These conceptual reviews are interesting in the mathematics education field, however, it seems that no contribution to improving contextual problems and direct specific research agendas are made.

Pedagogical innovations in this study are defined as actions of developing new learning resources as interventions for improving educational practices. No single definition exists for this term; it depends on the context and purpose of the term being used in studies. For instance, in the Second Information Technology in Education Study Module 2 (SITES M2), an international comparative study of innovative pedagogical practices using technology projects, Law et al. (2005) characterised the innovations based on technology-supported significant changes in learning practices that lead to positive student outcomes and are sustainable and transferable. In the higher education context, pedagogical innovations were simply characterized by an intentional action that aims to improve university students’ learning in a sustainable manner (Walder, 2014). Meanwhile, today's pedagogical innovations often relate to smart technologies used in learning and instruction processes (Law et al., 2003; Nachmias et al., 2004; Mioduser et al., 2004; Manning et al., 2017; Owston, 2007) with the main aim of facilitating learning and improving performance. However, in this study, both technology-based and non-technology-based innovations were taken into consideration.

The present study describes innovations of teaching and learning in mathematics, identifies underlying problems, and outlines models used in the previous studies in order to provide room for further improvement and propose a comprehensive forthcoming research agenda. Employing a systematic literature review, the study examines published scholarly articles from 2014 to 2019 with respect to the national implementation of a new Indonesian school curriculum called *Kurikulum 2013* at the beginning of 2014. The study is part of a PhD design-based research on developing some interventions and producing theories, principles, and resources in mathematics learning.

The result of this study aims to reveal the current state of educational reforms in Indonesia from the case of mathematics learning and instruction in elementary schools. Through the implementation of the new curriculum, a variety of innovations are introduced in terms of providing alternative sources for learning mathematics. The innovations address multiple problems with regard to students, teachers, and learning resources themselves. The previous research and development studies are incomplete since those do not address theoretical aspects, the studies thus should be improved seriously in the future. Starting by identifying the innovations and the underlying problems, and portraying the research and development models, this article proposes future research directions. Therefore, its findings discuss academic considerations, practical implications, and avenues for forthcoming studies.

Method

The method of this study was a systematic literature review. As a research method, the review investigates relevant previous research for collecting and analysing data (Liberati, 2009) to identify empirical evidence based on pre-specified inclusion criteria to answer a particular research question or hypothesis (Snyder, 2019). The review, therefore, is fruitful for revealing emerging phenomena as well as directing new research to address further questions (Newman & Gough, 2020). In this study, the systematic literature review was taken into account to know what is already known from research and development in mathematics learning in Indonesian elementary schools conducted from 2014 to 2019 and to provide future research directions. The time frame was taken with regard to the national implementation of *Kurikulum 2013* at the beginning of 2014. Furthermore, the process of literature review conducted in this study follows the step-by-step phases provided by Snyder (2019, p. 338) while the strategy was adapted from Snyder et al. (2016) and Witell et al. (2016) as illustrated in the following figure.

Google Scholar database:

196 articles

Selected for further analysis:

71 articles

Final sample:

59 articles

Themes:

1. Pedagogical innovations
2. Underlying problems
3. Development models

Search keywords:

“Pengembangan pembelajaran matematika di Sekolah Dasar Indonesia”

“Mathematics learning developments in Indonesian elementary schools”

Excluded after second reading (n=12)

Inclusion criteria:

1. Main focus on research and development
2. Conducted within mathematics learning in elementary schools
3. Published on journals or proceedings between 2014 and 2019
4. Written in Bahasa Indonesia and English
5. Full text access

Data abstraction and analysis

Figure 1. Search Strategy of the Literature Review

Figure 1 describes the strategy used in this literature review study. Two highly specific keywords (see figure 1) were used to search scholarly articles in the Google Scholar result in 196 articles downloaded manually from the database. The search focuses on Google Scholar to retrieve as many articles as possible through the specific keywords. Scopus or Web of Science was not used owing to the very limited number of published papers from Indonesia with respect to the keywords on the databases. From the 196 articles downloaded originally, 71 were selected for further analysis based on inclusion criteria including the focus on research and development within mathematics learning in elementary schools, published either in journals or proceedings from 2014 to 2019, and written in Bahasa Indonesia and/or English with full-text access. After conducting the second reading, 12 articles were excluded owing to the research in the articles conducted in the context of the former school curriculum in Indonesia called *Kurikulum Tingkat Satuan Pendidikan (KTSP).* Finally, 59 final sample manuscripts were processed for abstraction and further analysis qualitatively by the themes, namely pedagogical innovations, underlying problems, and development models.

The qualitative analysis implements both deductive and inductive coding. Theory in educational technology was employed to code deductively the category of pedagogical innovations and the identification of underlying problems. The innovations were categorised based on the classification of learning resources (AECT Task Force on Definition and Terminology, 1977): message, people, material, device, technique and setting. Meanwhile, the main actors and elements of teaching and learning processes in schools that include students, teachers, and learning resources were utilised to classify the problems. The inductive coding was applied to describe development models commonly used in the existing studies.

Results and Discussions

Existing research and development studies have been systematically studied in terms of portraying innovative pedagogical practices and formulating forthcoming study agendas. The results of the study include pedagogical innovations, underlying problems, and development models that are presented in the following passages. Academic considerations and practical implications are discussed within the findings. Accordingly, future research directions are formulated to direct what scholars should investigate in the future.

Pedagogical Innovations

As explained in the introduction, pedagogical innovations in this study focus on learning resources development as interventions for refining mathematics education practices. The data was tabulated based on the category and kind of learning resources with further detail about the articles, percentage and authors. There were only three categories of learning resources commonly developed in the existing studies, which can bee seen in the table below.

Table 1. Pedagogical Innovations in Mathematics Learning

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Category** | **Kind** | **Articles** | **Percentage** | **Authors** |
| Material | Board game | 3 | 5.08% | Siswoyo (2015), Fathurrohman, Nindiasari, & Rahayu (2016), Amir & Wardana (2017) |
| Comic | 1 | 1.69% | Indaryati & Jailani (2015) |
| Computer game | 2 | 3.39% | Yunus, Astuti, & Khairina (2015), Utami (2017) |
| Digital book | 1 | 1.69% | Yunianto, Negara, & Suherman (2019) |
| Digital game | 3 | 5.08% | Hartono, Candramata, Adhyatmoko, & Yulianto (2016), Puspita & Surya (2017), Rohendi, Sumarna, & Sutarno (2017) |
| Electronic module | 1 | 1.69% | Buchori & Rahmawati (2017) |
| Handout | 1 | 1.69% | Ningtyas, Yunianta, & Wahyudi (2014) |
| Instructional kits | 5 | 8.47% | Fauziyah & Jailani (2014), Fitriyanti (2016), Amir (2018), Anugraheni (2018), Nahdi & Cahyaningsih (2018) |
| Interactive multimedia | 6 | 10.17% | Waskito (2014), Afrizal (2015), Batubara (2015), Zainil, Prahmana, Helsa, & Hendri (2017), Pardimin, Ninsiana, Dacholfany, Kamar, Teh, Huda & Maseleno (2018), Hanifah, Arifuddin, Walid, Padil, Bashith, & Busro (2019) |
| Mobile application | 4 | 6.78% | Arif (2014), Ependi (2016), Batubara (2018), Rudyanto, Ghufron, & Hartono (2019) |
| Mobile game | 3 | 5.08% | Sutopo (2017), Sutopo & Pamungkas (2017), Amrulloh, Risnasari, & Ningsih (2019) |
| Module | 2 | 3.39% | Ahdhianto (2016), Habibi (2014) |
| Textbook | 3 | 5.08% | Maharani (2017), Nelawati, Meriyati, Putra, & Simatupang (2018), Desyandri, Muhammadi, Mansurdin, & Fahmi (2019) |
| Traditional media | 6 | 10.17% | Harnanto (2016), Hendratni (2016), Purnama, Irawan & Sadijah (2017), Arima & Indrawati (2018), Barus (2018), Wulandari & Mawardi (2018) |
| Worksheet | 5 | 8.47% | Febriya, Pranata, & Apriliya (2015), Hidayat & Irawan (2017), Fitri, Noviana, & Fendrik (2017), Dores & Setiawan (2018), Lestari, Pamungkas, & Alamsyah (2019), |
| Total |  | 46 | 77.97% |  |
| Technique | Instructional design | 4 | 6.78% | Astuti & Purwoko (2017), Muharram (2017), Mulbar & Zaki (2018), Zulkardi & Kohar (2018) |
| Instructional model | 5 | 8.47% | Tarjiah (2015), Fauziah (2016), Ariani, Helsa, Ahmad, & Prahmana (2017), Hamdi & Kartowagiran (2018), Hayati, Fauzan, Iswari, & Khaidir (2018) |
| Learning trajectory | 1 | 1.69% | Fauzan & Sari (2017) |
| Task design | 1 | 1.69% | Duskri, Kumaidi, & Suryanto (2014) |
| Total |  | 11 | 18.64% |  |
| Setting | Augmented reality | 1 | 1.69% | Amir (2019) |
| Virtual reality | 1 | 1.69% | Sulistyowati & Rachman (2017) |
| Total |  | 2 | 3.39% |  |

Table 1 outlines pedagogical innovations in teaching and learning of mathematics. The vast majority of the innovations are about developing learning materials while there are a few numbers of learning environment developments. Over 75% of the articles examined deal with learning material developments whilst around 18% and fewer than 5% of the articles work with learning technique and learning setting. Looking into the data in more detail, several kinds of learning material commonly developed for mathematics learning, namely instructional kits, interactive multimedia, worksheets, and media in the traditional forms as well as instructional models reached at over 8% of the articles. Conversely, the development of comics, digital books, electronic modules, handouts, learning trajectory, and task design as well as augmented and virtual reality learning environments is not common. Developments such as developing computer, digital, and mobile games could be categorised as the least common ones.

The number of interactive multimedia development as many as traditional media development. It implies that the media in a conventional form is still needed and remains relevant for teaching and learning of mathematics in Indonesian elementary schools. For instance, Harnanto (2016), Purnama, Irawan & Sadijah (2017), and Arima & Indrawati (2018) develop multiplication and division boxes to facilitate learning and enhance students’ understanding of multiplication and division in mathematics. In addition, tangram boards and a home miniature have also been developed to understand particular geometrical formulas, shapes, and concepts (Hendratni, 2016; Barus, 2018; Wulandari & Mawardi, 2018). Respecting interactive multimedia, the developments employed the Adobe Flash Media programme. However, most of them, and most mobile application media, merely bring text on board with minimum additions of multimedia and gamification elements such as story, character, interactive feedback, animation and sounds effects, badges, points, and leader boards (Kennedy & McNaught, 1997; Brigham, 2015) that stimulate students’ learning engagement.

Several games have been designed and developed in various ways to provide students with enjoyment and cheerfulness while learning mathematics. Nevertheless, almost all of the developed games exclusively address mathematical contents; there was only one game created by Amir & Wardana (2017) taking mathematical skills into account. Arithmetics and geometry are by far the most popular mathematics content which appears in these games. Aside from the game content, it is interesting that Utami (2017) develops a computer game for mentally disabled students introducing the basic concept of numbers and simple addition. On the whole, the games variety including board, computer, digital, and mobile games raise a signal that multiple approaches should be administered in order to contextually support joyful mathematics learning in the diverse circumstances of Indonesian elementary schools.

New instructional designs and models have also been introduced in terms of reforming mathematics education practices. It is interesting to see that the great values of Indonesian local culture could be integrated into mathematics learning and utilised as learning resources by the application of ethnomathematics learning design (Astuti & Purwoko, 2017). A didactical design was created by Muharram (2017) to help teachers in teaching mathematics and the realistic mathematics education (RME) concept was employed by Mulbar & Zaki (2018) to design higher-level-thinking mathematics learning. Interestingly, a PISA-like mathematics task has also been developed by Zulkardi & Kohar (2018) to promote mathematical literacy in Indonesia. In respect to the learning models, the previous scholars have developed learning models with particular regards to their study context. One great example is what has been done by Hayati, Fauzan, Iswari, & Khaidir (2018) in developing a model of holistic mathematics education (HME) for the low-grade primary school students to lay a solid foundation of mathematics.

It was not popular to develop a learning environment and other learning resources have not been addressed. Innovations of the learning environment attempted to use augmented and virtual reality with three-dimensional (3D) objects for learning geometrical shapes and practicing number additions (Amir, 2019; Sulistyowati & Rachman, 2017). Unfortunately, as yet no previous studies working with messages, devices and people for learning and instruction in elementary school mathematics subjects. A plethora of digital or non-digital texts and images are available in many places and media for reusable learning objects (Wiley, 2000) or knowledge objects (Merrill et al., 1991), which can be categorised as messages for learning. Intentionally developing people as a learning resource sounds challenging while device developments are fairly expensive that usually produced by corporates.

Underlying Problems

Problems underlie the pedagogical innovations are addressed in this section. The data was tabulated based on the learning actors and specific aspects including further detail about problems, examples and authors. Multiple issues with regard to students, teachers, and learning resources have been identified as backgrounds that motivate the breakthroughs in mathematics teaching and learning processes shown in the following table.

Table 2. Problems Underlying Pedagogical Innovations in Mathematics Learning

|  |  |  |  |
| --- | --- | --- | --- |
| **Actors** | **Aspects** | **Problems** | **Authors** |
| Student | Comprehension | Lack of understanding | Buchori & Rahmawati (2017), Hidayat & Irawan (2017), Maharani (2017), Muharram (2017), Amir (2018), Lestari, Pamungkas, & Alamsyah (2019) |
|  | Skills | Not familiar with analytical tasks and problem-solving | Astuti & Purwoko (2017), Hidayat & Irawan (2017), Nahdi & Cahyaningsih (2018) |
|  | Literacy | Low mathematical literacy | Dores & Setiawan (2018) |
|  | Misconception | Confused in mentioning concepts and formulas | Batubara (2018) |
|  | Perception | Students do not like mathematics and are considered as a difficult subject | Afrizal (2015), Fathurrohman, Nindiasari, & Rahayu (2016), Wulandari & Mawardi (2018), Desyandri, Muhammadi, Mansurdin, & Fahmi (2019) |
| Teacher | Knowledge | No understanding of metacognition, learning difficulties, and technologically stuttered | Tarjiah (2015), Zainil, Prahmana, Helsa, & Hendri (2017), Amir (2018) |
|  | Method | Theoretical and mechanistic learning, tend to memorize rather than understanding, merely transferring information without a constructive activity, teacher-centred, monotonous teaching | Fauziyah & Jailani (2014), Waskito (2014), Febriya, Pranata, & Apriliya (2015), Ahdhianto (2016), Ependi (2016), Astuti & Purwoko (2017), Fauzan & Sari (2017), Maharani (2017), Purnama, Irawan & Sadijah (2017), Zainil, Prahmana, Helsa, & Hendri (2017), Hayati, Fauzan, Iswari, & Khaidir (2018), Desyandri, Muhammadi, Mansurdin, & Fahmi (2019) |
|  | Media | No variation, not interesting, and mere relying on textbooks and worksheets | Batubara (2015), Siswoyo (2015), Harnanto (2016), Fauzan & Sari (2017), Utami (2017), Lestari, Pamungkas, & Alamsyah (2019), Yunianto, Negara, & Suherman (2019) |
|  | Lesson plan | Do not develop their own lesson plans | Anugraheni (2018) |
|  | Time | Limited time to do exercises and use other resources | Arif (2014), Ependi (2016), Purnama, Irawan & Sadijah (2017) |
|  | Evaluation | Lack of competency in preparing assessment tools | Hamdi & Kartowagiran (2018) |
| Learning resource | Textbook | Less interesting, hard to understand, more texts than pictures, some of the content is not hierarchical | Indaryati & Jailani (2015), Desyandri, Muhammadi, Mansurdin, & Fahmi (2019), Hanifah, Arifuddin, Walid, Padil, Bashith, & Busro (2019) |
|  | Worksheet | Only contains a summary of material and questions without relation to daily-life context | Ningtyas, Yunianta, & Wahyudi (2014), Febriya, Pranata, & Apriliya (2015), Hidayat & Irawan (2017), Fitri, Noviana, & Fendrik (2017), Lestari, Pamungkas, & Alamsyah (2019) |

Table 2 reveals a variety of problems underlying the breakthrough in mathematics educational practices. Various problems arise in relation to students, teachers, and learning resources. Some issues related to students include comprehension, skills, literacy, misconception, and perception about mathematics. The students have a low comprehension and negative perception of mathematics learning. Teachers suffer under critical problems with respect to their knowledge, teaching method and media, lesson plan, time, and learning evaluation. Lack of knowledge resulting in traditional ways of teaching and learning generate more complicated problems for the teachers. Regarding the resources for learning, old-fashioned textbooks and worksheets make teaching complicated. Those are less interesting due to the text-dominated content with no relation to daily life context.

It is evident from the findings that Indonesian elementary students have low mathematical comprehension, skills, and literacy as well as a negative perception of mathematics. The criticised students’ problems with understanding are mainly about mathematical concepts of multiplication and division and geometry. In fact, it was hard for students to deal with mathematics multiplication and division assignments (Maharani, 2017; Harnanto, 2016) and identify geometrical shapes (Buchori & Rahmawati, 2017; Muharram, 2017). This seems to be the case due to the lack of higher order thinking skills and mathematical literacy, such as reasoning and problem solving (Hidayat & Irawan (2017) and metacognition (Amir, 2018). Furthermore, students acknowledged that mathematics is a difficult (Afrizal, 2015), scary (Fathurrohman, Nindiasari, & Rahayu, 2016), full-of-formula-memorising (Wulandari & Mawardi, 2018), and boring (Desyandri, Muhammadi, Mansurdin, & Fahmi, 2019) subject.

The lack of teachers’ knowledge hand in hand with the traditional ways of teaching commonly used by teachers in the classroom leads to more complicated problems. The teachers have no idea concerning metacognition (Amir, 2018) and students’ learning difficulties (Tarjiah, 2015). In addition, although some schools have been equipped with multimedia supported classrooms, the teachers were unable to utilise the technologies (Zainil, Prahmana, Helsa, & Hendri, 2017). As a result, the ways the teachers teach are merely theoretical and mechanistic (Fauziyah & Jailani, 2014; Ependi, 2016), tend towards memorising rather than understanding (Febriya, Pranata, & Apriliya, 2015; Fauzan & Sari, 2017; Maharani, 2017; Hayati, Fauzan, Iswari, & Khaidir, 2018), transfer information without a constructive activity (Ahdhianto, 2016; Purnama, Irawan & Sadijah, 2017), and are teacher-centred (Astuti & Purwoko, 2017). The media used by teachers are also monotonous (Batubara, 2015; Yunianto, Negara, & Suherman, 2019) and teachers rely only on textbooks and worksheets (Siswoyo, 2015; Utami, 2017; Lestari, Pamungkas, & Alamsyah, 2019).

The textbooks and worksheets themselves, as the main learning resources, were old-fashioned. The textbooks were dominated by texts with minimum images so that they are less attractive and meaningful to students (Indaryati & Jailani, 2015; Hanifah, Arifuddin, Walid, Padil, Bashith, & Busro, 2019). Another issue is that the textbooks' content structure was not hierarchical with respect to mathematical concepts (Desyandri, Muhammadi, Mansurdin, & Fahmi, 2019). Regarding the worksheets, those contents were just summaries of materials and questions without any relation to daily-life context (Ningtyas, Yunianta, & Wahyudi, 2014); Febriya, Pranata, & Apriliya, 2015; Hidayat & Irawan, 2017; Fitri, Noviana, & Fendrik, 2017; Lestari, Pamungkas, & Alamsyah, 2019). These are serious issues since learning resources play a pivotal role in teaching and learning processes, and those absences degrade student's learning achievements (Author et al., 2018). Hence, the problems are relatively complex and interrelated among students, teachers, and learning resources.

Development models used in the studies

Variety models of research and development have been implemented in the previous studies for developing pedagogical innovations in Indonesian mathematics education. The data was tabulated (see table 3) based on the models with further detail about the articles, percentage and authors. The development models in the existing studies include 4D (define, design, develop, and disseminate), ADDIE (analysis, design, development, implementation, and evaluation), Borg & Gall, Dick & Carey, DDR (didactical design research), design research, IDI (instructional development institute), Luther's development model, MADCL (mobile application development lifecycle), Mardapi test development model, Scrum, and Waterfall.

Table 3. Models Used for Developing Pedagogical Innovations in Mathematics Learning

|  |  |  |  |
| --- | --- | --- | --- |
| **Models** | **Articles** | **Percentage** | **Authors** |
| 4D | 9 | 15.25% | Fauziyah & Jailani (2014), Buchori & Rahmawati (2017), Purnama, Fitriyanti (2016), Irawan & Sadijah (2017), Amir (2018), Anugraheni (2018), Nelawati, Meriyati, Putra, & Simatupang (2018), Mulbar & Zaki (2018), Lestari, Pamungkas, & Alamsyah (2019) |
| ADDIE | 12 | 20.34% | Ningtyas, Yunianta, & Wahyudi (2014), Ariani, Puspita & Surya (2017), Fitri, Noviana, & Fendrik (2017), Hidayat & Irawan (2017), Helsa, Ahmad, & Prahmana (2017), Sulistyowati & Rachman (2017), Zainil, Prahmana, Helsa, & Hendri (2017), Arima & Indrawati (2018), Nahdi & Cahyaningsih (2018), Amrulloh, Risnasari, & Ningsih (2019), Hanifah, Arifuddin, Walid, Padil, Bashith, & Busro (2019), Rudyanto, Ghufron, & Hartono (2019) |
| Borg & Gall | 13 | 22.03% | Duskri, Kumaidi, & Suryanto (2014), Batubara (2015), Indaryati & Jailani (2015), Siswoyo (2015), Tarjiah (2015), Hendratni (2016), Fathurrohman, Nindiasari, & Rahayu (2016), Sutopo (2017), Sutopo & Pamungkas (2017), Barus (2018), Dores & Setiawan (2018), Wulandari & Mawardi (2018), Yunianto, Negara, & Suherman (2019) |
| Borg & Gall + 4D | 2 | 3.39% | Batubara (2018), Desyandri, Muhammadi, Mansurdin, & Fahmi (2019) |
| Borg & Gall  + Dick & Carey | 1 | 1.69% | Maharani (2017) |
| DDR | 1 | 1.69% | Muharram (2017) |
| Design research (Gravemeijer & Cobb, 2006) | 3 | 5.08% | Astuti & Purwoko (2017), Fauzan & Sari (2017), Amir (2019) |
| Design research (Plomp, 2013) | 3 | 5.08% | Ahdhianto (2016), Amir & Wardana (2017), Hayati, Fauzan, Iswari, & Khaidir (2018) |
| Design research (McKenney & Reeves, 2014) | 1 | 1.69% | Febriya, Pranata, & Apriliya (2015) |
| Dick & Carey | 1 | 1.69% | Fauziah (2016) |
| IDI | 1 | 1.69% | Habibi (2014) |
| Luther's development model | 1 | 1.69% | Utami (2017) |
| MADLC | 1 | 1.69% | Ependi (2016) |
| Mardapi test development model | 1 | 1.69% | Hamdi & Kartowagiran (2018) |
| Scrum | 1 | 1.69% | Hartono, Candramata, Adhyatmoko, & Yulianto (2016) |
| Waterfall | 2 | 3.39% | Arif (2014), Afrizal (2015) |
| No model | 5 | 8.47% | Waskito (2014), Yunus, Astuti, & Khairina (2015), Harnanto (2016), Rohendi, Sumarna, & Sutarno (2017), Pardimin, Ninsiana, Dacholfany, Kamar, Teh, Huda & Maseleno (2018) |

Table 3 describes the models commonly used for developing innovations of teaching and learning in mathematics. Some models are more frequently applied for the development compared to others. The 4D, ADDIE, and Borg & Gall development models by far are the most popular models implemented in the previous studies, reaching over 55% of the articles. Other models such as IDI, MADLC, and Scrum are merely used in under 5% of the studies, with the exception of design research. Unfortunately, around 8% of research and developments in mathematics learning was conducted without any model. It is also important to note that some studies combined two development models.

Since the Borg & Gall, ADDIE, and 4D models were used very often in many previous studies, exploring other models such as IDI, MADLC, and Scrum should be of further interest for the next studies. It is true that Borg & Gall, ADDIE, 4D, and Dick & Carey instructional development models are recognised as prominent models widely used in the educational technology field, however, using a more appropriate recent model with regard to particular product development is important rather than just continuing the tradition. For example, as the study of Ependi (2016) decides to use MADLC for developing a mathematics mobile application and Hartono, Candramata, Adhyatmoko, & Yulianto (2016) employ the SCRUM to develop a digital game of mathematics. The more suitable the development model, the better the developed product.

Although some studies apply development models containing a dissemination phase as seen in the Borg & Gall and 4D models, no one in the previous studies continue their development until the dissemination stage. For instance, Yunianto, Negara, & Suherman (2019) develop a digital mathematics flipbook by using the Borg & Gall model to help students in learning flat geometrical shapes limited to product revision whilst an electronic module of geometry based on the realistic mathematics approach was developed by Buchori & Rahmawati (2017) using the 4D model with no dissemination activities. Furthermore, there are studies merely developing the product without any testing by experts or users, and some studies were unfortunately conducted unaccompanied by a particular model. For examples, when applying the Waterfall model, Arif (2014) and Afrizal (2015) were not conducting expert and user testing in the development of a mathematics mobile application and multimedia interactive program. Yunus, Astuti, & Khairina (2015) and Rohendi, Sumarna, & Sutarno (2017) create computer games without respecting the existing development model.

A good example is provided by Hamdi & Kartowagiran (2018) who develop a mathematics test instrument by following step-by-step Mardapati’s test development model and trying the instrument massively on 552 students in 14 elementary schools located in the urban, border, and rural areas of Indonesia. It is true that research and development is highly demanding. On the global scale, this kind of research requires extensive financial funding and investment (Hall et al., 2016). Therefore, it is reasonable that there are many limitations in the previous development research examined in this study. Likewise, the research was conducted solely by bachelor or master students. Dealing with the funding issue, having university-industry-government collaborations (Leydesdorff & Etzkowitz, 1996) could be the solution. Another possible solution is that the bachelor or master students continue their research and development into the dissemination stage when taking a further degree at university.

The various versions of design research implemented in Indonesia show that there are many perspectives toward the research. Unfortunately, it seems that there is a misconception of design research concepts due to the existing design research which only focus on practice and make no contribution to theory. For example, Febriya, Pranata, & Apriliya (2015) employed the design research from McKenney & Reeves (2014) for developing a student worksheet without formulating design principles, conjecture maps, or learning trajectories. Likewise, the other design-based studies conducted by using the design research from Gravemeijer & Cobb (2006) and Plomp (2013) suffer from minimum theoretical contributions. Another important point to note is that the findings in previous studies were monotonous and predictable. Most of the final findings merely stated that their product is valid, practicable, and effective whilst critical discussions to improve practices and refine theories were not available.

Future research directions

Reviewing pedagogical innovations established in mathematics subject in Indonesian elementary schools points out future research agendas. The next innovations have to go beyond developing learning materials and techniques: bringing the development of messages, devices, people and learning environments to the fore is the direction. When inventing conventional or highly technology savvy resources for learning the creation should not only take texts to another new media but the characteristic of the media should be included as well. More studies addressing mathematical skills and literacy are needed although mathematical contents are also important. The mathematics serious games development on multiple platforms is inevitable to be pushed forward since those fruitful for providing amusement in learning (de Freitas, 2006; Crookall, 2010). Looking in more detail into the Indonesian context, the heterogeneous state of Indonesian elementary schools must be taken into consideration more seriously. In addition to this, the Indonesian innovators of education ought to act locally while thinking globally. The local culture and wisdom of Indonesia could be integrated into the pedagogical innovations to face global challenges.

Forthcoming studies are challenged to find out the best solutions to the interrelated complex problems among the students, teachers, and learning resources. Research working on how to provide a positive first impression toward mathematics to students is of fundamental importance before improving mathematical comprehension, skills, and literacy. Exploring serious games in mathematics teaching and learning practices to change students’ negative perspective toward mathematics is expected to be one of the best solutions. At the same time, upgrading in-service teachers’ knowledge as well as preparing knowledgeable pre-service teachers for teaching mathematics is part of further primary investigation. This could be a study of developing technological pedagogical content knowledge or TPACK (Koehler & Mishra, 2005; Mishra & Koehler, 2006) leading to more technological-pedagogical-content literate teachers for teaching mathematics creatively and innovatively by harnessing various appropriate technologies. Moreover, the textbooks and worksheets should be redesigned and redeveloped according to hierarchical mathematical concepts with more images and relation to daily-life context. These complicated issues, therefore, should be addressed in a systematic and comprehensive means.

The way in which research and development is conducted by Indonesian scholars in the subject of mathematics in elementary schools should also be enhanced. Applying a recent corresponding development model is suggested to create a high-quality specific product. More importantly, once a model is taken, the research is required to carefully follow every single step of the chosen model. Especially towards design research, it is pivotal to note that the research should contribute to the theory and practice simultaneously (Bakker, 2018). The more serious point to address is that plethora research and development findings and products are just displayed on the shelf. Therefore, disseminating those findings and products is highly recommended so the findings could be adopted to improve educational practices and theories. Finally, it is meaningless to just claim that the product is valid, practicable, and effective. As a consequent, a comprehensive discussion on what is the implication to the practice and theory should be available.

Conclusion

The pedagogical innovations in Indonesian elementary schools' mathematics learning were mainly about developing learning materials and techniques. After carefully identifying the innovations, the recommendation for the next studies is working with messages, devices, people and learning environments that address mathematical skills and literacy added with local culture and wisdom of Indonesia. Regrettably, Indonesian elementary students have a negative view towards mathematics while the teachers are less competent in teaching and the learning resources are out-dated. Integrating serious games into mathematics instruction appeals to stimulate students' positive perception of mathematics. A systematic and comprehensive way, therefore, is required to solve the multiple issues. Several prominent and recent development models have been applied in previous mathematics education research and development. Adopting the recent development model with regard to study aim and context as well as systematically following the chosen model steps are the forthcoming calls to action. For scholars who wish to conduct design research, bear in mind that the research must contribute to theory and practice simultaneously. Last but not least, it is pivotal importance to consider deeper discussion and disseminate research and development findings into future endeavours.

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