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Pedagogical Innovations in Elementary Mathematics Instructions: Future Learning and Research Directions

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Abstract

Literature reviews about pedagogical innovations are of importance to determine further interventions for learning refinement and future research directions. The present study describes existing pedagogical innovations, identifies learning problems underlie the innovations, and outlines development models used for developing elementary mathematics educational innovations in Indonesia. A systematic literature review was administered to review scholarly articles published between 2014 and 2019. This time frame was drawn in relation to a new curriculum called Kurikulum 2013 introduced in early 2014. The results of this study reveal that the majority of pedagogical innovations focus on developing learning materials and techniques while fewer innovations develop learning environments. Problems underlie existing innovations mainly due to the elementary students who reluctant to learn mathematics, the less competent teachers, and the old-fashioned learning resources. Research and development in elementary mathematics were commonly conducted using Borg & Gall, ADDIE, and 4D models. The evidence from this study suggests that forthcoming mathematics teaching and learning process should be conducted in more enjoyable manners such as practicing microgame-based learning in either physical or digital learning spaces. One of the most sensible research agendas is to develop joyful learning environments to address the interrelated complex problems among students, teachers, and learning resources in elementary mathematics learning in Indonesia.

Introduction

Literature reviews about pedagogical innovations are of importance to determine further interventions for learning 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 research gaps, 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 more precisely address contextual problems.

Educational innovations in elementary mathematics learning in Indonesia have not been clearly described in a systematic way leading to the lack of future learning and research directions. Several recent literature reviews about Indonesian mathematics learning merely conceptually discuss particular issues such as project-based learning with realistic mathematics education (Handayani et al., 2019), mathematics concept based on traditional arts (Wulandari & Mariana, 2018), and mathematical modeling (Hartono & Karnasih, 2017). Although these simple literature reviews are indeed interesting, those have few contributions to solve contextual learning problems and direct specific research agendas. Therefore, conducting a systematic literature review about the pedagogical innovations could contribute not only to learning practices but also to educational research enactments.

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) characterize 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 characterised by an intentional action that aims to improve university students' learning in a sustainable manner (Walder, 2014). It seems that practical improvement is the keyword for every single innovation.

The novelty of this study is twofold. First, the study reveals pedagogical innovations in the school context. There are many learning innovation research conducted in higher education (e.g., Walder, 2014 & 2017; Conole et al., 2008; Laurillard, 2008; Furco & Moely, 2012) while few investigations organized in school settings. Only the SITES M2 project is probably a pedagogical innovation study in the school. Several papers about pedagogical innovations in schools relate to this project. However, the project focuses on digital technology-based educational transformation. Therefore, the second novelty is that the innovations taken on board in this study are based on analogue and digital technology. Latest pedagogical innovations often relate to smart technologies for facilitating learning and improving performance (Law et al., 2003; Nachmias et al., 2004; Mioduser et al., 2004; Manning et al., 2017; Owston, 2007). Apart from the high technology-based innovation, improvements facilitated by low technologies have to be recognized as innovation as well.

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 rooms for learning improvement and propose forthcoming research agendas. Employing a systematic literature review, the study examines published scholarly articles on academic journals and proceedings from 2014 to 2019 with respect to the national implementation of a new Indonesian school curriculum called *Kurikulum 2013* at the beginning of 2014. Starting by describing the innovations, identifying the problems, and portraying the research and development models, this study proposes future learning and research directions.

Method

The method of this study was a systematic literature review. As a research method, the review investigates relevant previous research for collecting and analyzing 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* introduced in early 2014. Furthermore, the process of the 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 Figure 1.

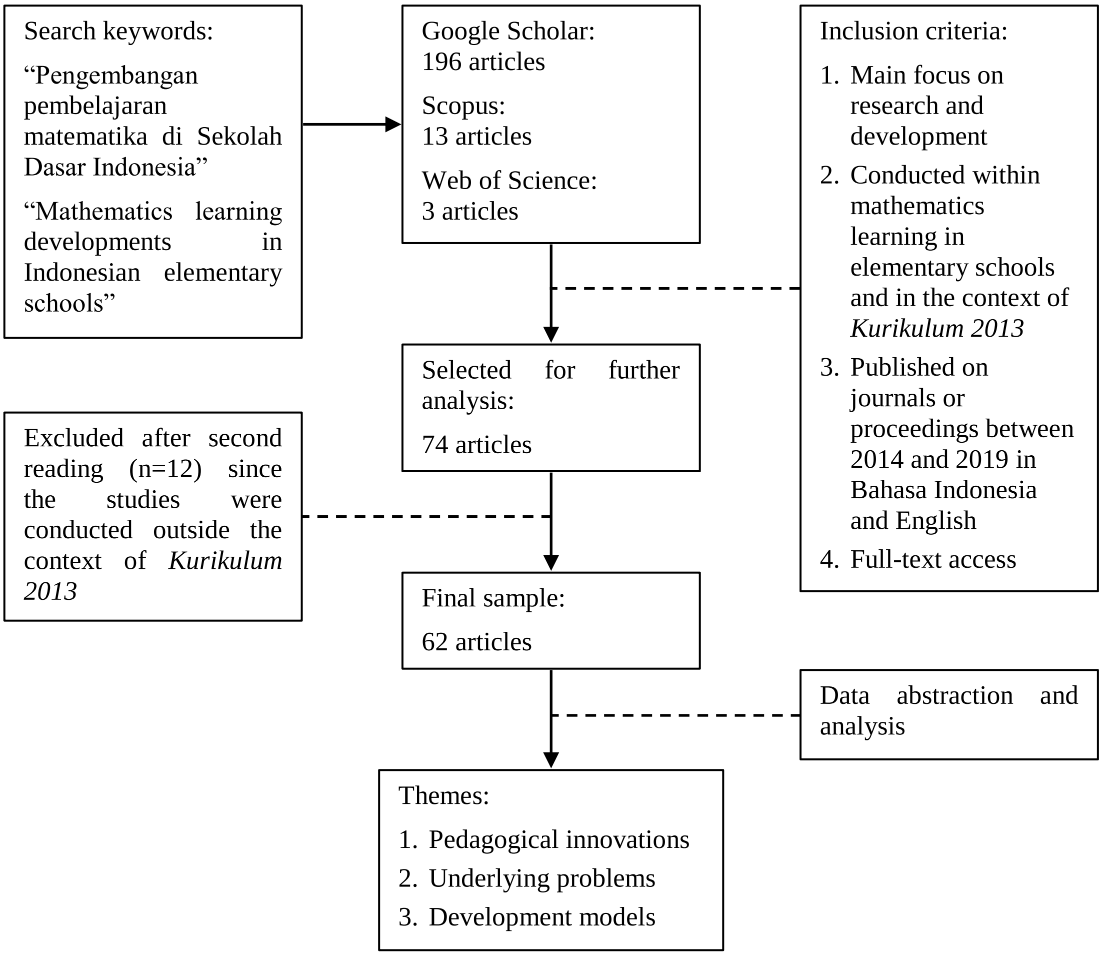

Figure 1. Search Strategy of the Literature Review

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 three different databases. There were found 196 articles in Google Scholar, 13 articles in Scopus, and 3 articles in Web of Science. From the 212 articles identified originally, 74 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, 62 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 categorized 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 utilized to classify the problems. The inductive coding was applied to describe development models commonly used in the existing studies.

Results and Discussion

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 in the findings. Accordingly, future learning and 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 be seen in Table 1. Table 1 describes 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 20% 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 over 8% of the articles in each category. 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 categorized as the least common ones.

Table 1. Pedagogical Innovations in Mathematics Learning

Categories	Types	Articles	Percentage	Authors
Material	Board game	3	4.84%	Siswoyo (2015), Fathurrohman et al. (2016), Amir & Wardana (2017)
	Comic	1	1.61%	Indaryati & Jailani (2015)
	Computer game	2	3.23%	Yunus et al. (2015), Utami (2017)
	Digital book	1	1.61%	Yunianto et al. (2019)
	Digital game	3	4.84%	Hartono et al. (2016), Puspita & Surya (2017), Rohendi et al. (2017)
	Electronic module	1	1.61%	Buchori & Rahmawati (2017)
	Handout	1	1.61%	Ningtyas et al. (2014)
	Instructional kits	5	8.06%	Fauziyah & Jailani (2014), Fitriyanti (2016), Amir (2018), Anugraheni (2018), Nahdi & Cahyaningsih (2018)
	Interactive multimedia	6	9.68%	Waskito (2014), Afrizal (2015), Batubara (2015), Zainil et al. (2017), Pardimin et al. (2018), Hanifah et al. (2019)
	Mobile application	4	6.45%	Arif (2014), Ependi (2016), Batubara (2018), Rudyanto et al. (2019)
	Mobile game	3	4.84%	Sutopo (2017), Sutopo & Pamungkas (2017), Amrulloh et al. (2019)
	Module	2	3.23%	Ahdhianto (2016), Habibi (2014)
	Textbook	3	4.84%	Maharani (2017), Nelawati et al. (2018), Desyandri et al. (2019)
	Traditional media	6	9.68%	Harnanto (2016), Hendratni (2016), Purnama et al. (2017), Arima & Indrawati (2018), Barus (2018), Wulandari & Mawardi (2018)
	Worksheet	5	8.06%	Febriya et al. (2015), Hidayat & Irawan (2017), Fitri et al. (2017), Dores & Setiawan (2018), Lestari et al. (2019)
Total		47	75.81%	
Technique	Instructional design	5	8.06%	Astuti & Purwoko (2017), Muharram (2017), Mulbar & Zaki (2018), Zulkardi & Kohar (2018), Andrianingrum & Suparman (2019)
	Instructional model	6	9.68%	Tarjiah (2015), Fauziah (2016), Ariani et al. (2017), Hamdi & Kartowagiran (2018), Hayati et al. (2018), Widodo et al. (2019)
	Learning trajectory	1	1.61%	Fauzan & Sari (2017)
	Task design	1	1.61%	Duskri et al. (2014)
Total		13	20.97%	
Setting	Augmented reality	1	1.61%	Amir (2019)
	Virtual reality	1	1.61%	Sulistyowati & Rachman (2017)
Total		2	3.23%	

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 et al. (2017), and Arima & Indrawati (2018) develop multiplication and division boxes to facilitate learning and enhance students' understanding of multiplication and division in mathematics. Besides, 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 and Wardana (2017) taking mathematical skills into account. Arithmetics and geometry are by far the most popular mathematics content 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 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 et al. (2018) in developing a model of holistic mathematics education (HME) for the low-grade primary school students to lay a solid foundation of mathematics.

Developing learning environments seems less popular and the other learning resources have not been touched in the existing studies. 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 categorized as messages for learning. Developing people intentionally as a learning resource sounds challenging while device developments are fairly expensive that usually produced by corporates.

Underlying Problems

Problems underlying 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 Table 2.

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 et al. (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 et al. (2019)
Teacher	Knowledge	No understanding of metacognition, learning difficulties and technologically stuttered	Tarjiah (2015), Zainil et al. (2017), Amir (2018)
	Method	Theoretical and mechanistic learning, tend to memorize rather than understanding, merely transferring information without a constructive activity, teacher-centered, monotonous teaching	Fauziyah & Jailani (2014), Waskito (2014), Febriya et al. (2015), Ahdhianto (2016), Ependi (2016), Astuti & Purwoko (2017), Fauzan & Sari (2017), Maharani (2017), Purnama et al. (2017), Zainil et al. (2017), Hayati et al. (2018), Desyandri et al. (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 et al. (2019), Yunianto et al. (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 et al. (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 et al. (2019), Hanifah et al. (2019)
	Worksheet	Only contains a summary of material and questions without relation to the daily-life context	Ningtyas et al. (2014), Febriya et al. (2015), Hidayat & Irawan (2017), Fitri et al. (2017), Lestari et al. (2019)

Table 2 reveals a variety of problems underlying the breakthrough in mathematics educational practices. Various problems arise concerning students, teachers, and learning resources. Some issues related to students include comprehension, skills, literacy, misconception, and perception of mathematics. The students have a low comprehension and negative perception of mathematics learning. Teachers suffer under critical problems for 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 students' understanding problems 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 et al., 2016), full-of-formula-memorizing (Wulandari & Mawardi, 2018), and boring (Desyandri et al., 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). Although some schools have been equipped with multimedia-supported classrooms, the teachers were unable to utilize the technologies (Zainil et al., 2017). As a result, the ways the teachers teach are merely theoretical and mechanistic (Fauziyah & Jailani, 2014; Ependi, 2016), tend towards memorizing rather than understanding (Febriya et al., 2015; Fauzan & Sari, 2017; Maharani, 2017; Hayati et al., 2018), transfer information without a constructive activity (Ahdhianto, 2016; Purnama et al., 2017), and are teacher-centred (Astuti & Purwoko, 2017). The media used by teachers are also monotonous (Batubara, 2015; Yunianto et al., 2019) and teachers rely only on textbooks and worksheets (Siswoyo, 2015; Utami, 2017; Lestari et al., 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 et al., 2019). Another issue is that the textbooks content structure was not hierarchical to mathematical concepts (Desyandri et al., 2019). Regarding the worksheets, those contents were just summaries of materials and questions without any relation to daily-life context (Ningtyas et al., 2014); Febriya et al., 2015; Hidayat & Irawan, 2017; Fitri et al., 2017; Lestari et al., 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 (Rahmadi et al., 2018). Hence, the problems are relatively complex and interrelated among students, teachers, and learning resources.

Development Models

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	14.52%	Fauziyah & Jailani (2014), Buchori & Rahmawati (2017), Purnama & Fitriyanti (2016), Irawan & Sadijah (2017), Amir (2018), Anugraheni (2018), Nelawati et al. (2018), Mulbar & Zaki (2018), Lestari et al. (2019)
ADDIE	13	20.97%	Ningtyas et al. (2014), Ariani et al. (2017), Fitri et al. (2017), Hidayat & Irawan (2017), Helsa et al. (2017), Sulistyowati & Rachman (2017), Zainil et al. (2017), Arima & Indrawati (2018), Nahdi & Cahyaningsih (2018), Amrulloh et al. (2019), Hanifah et al. (2019), Rudyanto et al. (2019), Andrianingrum & Suparman (2019)
Borg & Gall	15	24.19%	Duskri et al. (2014), Batubara (2015), Indaryati & Jailani (2015), Siswoyo (2015), Tarjiah (2015), Hendratni (2016), Fathurrohman et al. (2016), Sutopo (2017), Sutopo & Pamungkas (2017), Barus (2018), Dores & Setiawan (2018), Wulandari & Mawardi (2018), Yunianto et al. (2019), Widodo et al. (2019)
Borg & Gall + 4D	2	3.23%	Batubara (2018), Desyandri et al. (2019)
Borg & Gall + Dick & Carey	1	1.61%	Maharani (2017)
DDR	1	1.61%	Muharram (2017)
Design research (Gravemeijer & Cobb, 2006)	3	4.84%	Astuti & Purwoko (2017), Fauzan & Sari (2017), Amir (2019)
Design research (Plomp, 2013)	3	4.84%	Ahdhianto (2016), Amir & Wardana (2017), Hayati et al. (2018)
Design research (McKenney & Reeves, 2014)	1	1.61%	Febriya et al. (2015)
Dick & Carey	1	1.61%	Fauziah (2016)
IDI	1	1.61%	Habibi (2014)
Luther's development model	1	1.61%	Utami (2017)
MADLC	1	1.61%	Ependi (2016)
Mardapi test development model	1	1.61%	Hamdi & Kartowagiran (2018)
Scrum	1	1.61%	Hartono et al. (2016)
Waterfall	2	3.23%	Arif (2014), Afrizal (2015)
No model	6	9.68%	Waskito (2014), Yunus et al. (2015), Harnanto (2016), Rohendi et al. (2017), Pardimin et al. (2018), Nurfadhillah et al. (2018)

Table 3 outlines 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 almost 60% of the articles. Other models such as IDI, MADLC, and Scrum are merely used in under 5% of the studies except for design research. Unfortunately, around 9% of research and developments in mathematics learning was conducted without using 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. Indeed, Borg & Gall, ADDIE, 4D, and Dick & Carey instructional development models are recognized as prominent models widely used in the educational technology field. The popularity of the models may due to the intensive introduction of those models in educational technology programs either for bachelor, master, or doctoral degrees in Indonesian higher education. However, using a more appropriate recent model concerning 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 continues their development until the dissemination stage. For instance, Yunianto et al. (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 et al. (2015) and Rohendi et al. (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 Mardapi'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. Research and development are indeed highly demanding. On a 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 focuses on practice and makes no contribution to theory. For example, Febriya et al. (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 Learning and Research Directions

Reviewing pedagogical innovations established in mathematics subject in Indonesian elementary schools points out future learning directions. As many of the innovations attempt to address problems related to students who reluctant to mathematics, the forthcoming mathematics teaching and learning processes should be conducted in more pleasurable ways. One possible solution is to practice game-based mathematics learning in Indonesian elementary schools. Learning that facilitated by games results in a variety of positive perception and behavior affecting student's motivation and performances (Connolly et al., 2012).

Serious games applications evidently increase learner motivation and completion rates (de Freitas, 2006) as well as boost learning performances and cognitive skills (Mayer, 2016 & 2019). Meanwhile, since learning duration is highly limited in formal schooling environments and teachers do not have enough time to develop their own games or purchase professional games with their own budget, teachers can take advantage from educational user-generated microgames (Rahmadi et al., 2021). Those are relatively small games that were created, modified, shared, and used by users in open learning platforms such as GeoGebra, PurposeGames, and Scratch with no commercial motives.

Respecting Indonesian circumstances that consist of urban and rural areas, the future of mathematics learning remain in need of integration between analogue and digital media. The idea behind is to have a solid connection and an active interplay between physical and digital learning activities, resources and environments (Lavicza et al., 2018; Mariotti & Montone, 2020; Komatsu & Jones, 2020). This connection appears potential to innovate mathematics learning processes and to gradually solve interrelated mathematics instructional problems in Indonesian elementary schools. Students have the opportunity to actively engage in multiple ways either with paper-and-pencil or digital-based learning activities provided by teachers (Komatsu & Jones, 2020). At the same time, teachers can adapt and adopt innovation smoothly since they could start from the conventional to digital ways of teaching (Lavicza et al., 2018). The interplay between traditional and modern technology may also enrich learning resources and environments so the learning of mathematics can be delivered more meaningfully and connected to a real-world context.

Regarding future research, the present literature review proposes some possible lines. 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 amusing learning (de Freitas, 2006; Crookall, 2010). Simulations are also fruitful to develop skills and literacies (Perdana et al., 2019). 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; Rahmadi, 2019) 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.

How Indonesian scholars conduct research and development in elementary mathematics learning 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. Particularly 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 of 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 present study has systematically reviewed pedagogical innovations in mathematics learning in Indonesian elementary schools. The aims were to describe the pedagogical innovations, identify learning problems that underlie the innovations, and outline development models used for developing the learning innovations. Following conclusions can be drawn from this study. First, the majority of pedagogical innovations focus on developing learning materials and techniques while fewer innovations develop learning environments. Second, problems underlie previous studies mainly due to the elementary students who reluctant to learn mathematics, the less competent teachers, and the old-fashioned learning resources. Third, research and development in elementary mathematics were commonly conducted by using Borg & Gall, ADDIE, and 4D models.

Recommendations

Taken together, the evidence from this study has twofold suggestions regarding future learning and research directions. Forthcoming mathematics teaching and learning processes should be conducted in more enjoyable manners by practicing game-based learning in physical and digital learning environments. Therefore, one of the most sensible research agendas is to develop such enjoyable learning environments to address the interrelated complex problems among students, teachers, and learning resources in elementary mathematics learning in Indonesia. The current investigation was limited to pedagogical innovations in a very specific context. Notwithstanding the limitation, the present study provides a new understanding of innovations for learning mathematics subject in elementary school.

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