A Large-scale PD Intervention for Improvement of Teachers' Mathematical Knowledge in Disadvantaged Communities

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Central to the conference theme "Research Impacting Practice", this paper presents the findings of a large-scale mathematics professional development (PD) intervention in disadvantaged communities in Indonesia. The study investigated the impact of a lesson design-driven PD on secondary mathematics teachers' content knowledge (CK). The Cascade Model was implemented in ten districts and involved 364 teachers. The PD workshops, needs analysis, scripted lesson designs and monitoring mechanisms inherent in the PD model, significantly increased teachers' CK. The findings gathered over a period of approximately one year further our understanding of the process of large-scale PD in challenging contexts.

Introduction

Teacher continuous professional development (PD) is a challenging endeavour as it requires working with professionals who have established practices, work under particular conditions, and are subject to expectations from parents and administrators. PD is thus a contextual enterprise that requires the consideration of a number of factors, internal to the teacher such as commitment, motivation, mindset, belief, value system, as well as external considerations such as support systems, school administration, and expectations from the complex education system (Maass & Engeln, 2018). This mix of internal and external factors makes professional development initiatives demanding for academics who develop initiatives based on needs analysis, educational reports, and innovations in the field of education. On the other hand, PDs are costly, time consuming and often extended over long periods of time requiring the concerted effort and deployment of different stakeholders. Consequently, the complex nature of PD has generated much academic interest. PD in mathematics has become its own field of research within the larger field of mathematics education research, with a growing body of scholarly publications (Desimone, 2009; Sztajn, 2011). Research on PD has brought evidenced-based awareness of critical issues such as fidelity of implementation, monitoring, and sustainability among others (Borko, 2004; Krainer, 2015). In the special ZDM issue, entitled "Evidence-based continue professional development: Scaling up sustainable interventions" (Roesken-Winter, Hoyles, & Blömeke, 2015), the authors unpacked the challenges of scaling up CPD from four perspectives: crucial aspect of teacher learning, CPD framework development, development of CPD in an evidence-based way as well as dimensions to characterise the process of scaling CPD interventions (i.e., depth, sustainability, spread, and shift in reform ownership). In their continuing efforts to make this professional learning process effective, educators have developed various models of PD, the focus of the present paper is the *Cascade Model*.

The Cascade Model of PD

The Cascade Model is a commonly used strategy in which a first cohort of teachers is trained in a particular program or content then this cohort becomes the trainer of the next wave of teachers (Hayes, 2000; Zehetmeier & Krainer, 2011). This process is continued to be able to reach larger numbers of program recipients. Thus, the Cascade Model seems to be an appropriate and effective option for a large-scale, long-term intervention.

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This model is commonly implemented in non-developed countries such as in South Africa (Ono & Ferreira, 2010), Sri Lanka (Hayes, 2000), Greece (Karalis, 2016) and Kenya (Bett, 2016). It is often adopted by education ministries in disseminating knowledge or programs to large numbers of teachers in a fast and cost-effective way. Past research suggests that the impacts of the model have been quite mixed. For example, Karalis (2016) reported on a Cascade Model in Greece, where more than 20 000 adult educators were trained and accredited to teach continuing vocational training activities and general adult education programs in less than fifteen years, and he claimed that the program was effective, based on reports by the majority of the participants who responded very positively to the program, rating it between 3.7 and 3.9 (out of 4.0) for their general impression and interest in the program. In contrast, Sifuna and Kaime (2007) reported the challenges of a project in Kenya called *Strengthening Mathematics and Sciences in Secondary Schools* (SMASSE) where the majority of the participating teachers had no interest in the program because the project did not meet their professional needs and provided limited instructional equipment to implement the project ideas in their classrooms.

In fact, many challenges of the Cascade Model are well known including: the potential for misinterpretation of content as the cascade moves to the lower levels, particularly when the training is concentrated at the top level (Hayes, 2000); programs are often conducted away from the school environment (Sifuna & Kaime, 2007); the pressure of time and performance on the teachers having additional responsibilities to facilitate other teachers while being responsible for the learning of their own students; inflexibility of responding to participants' contextual needs; and less attention to the learning and leadership development of trainers to carry out their role successfully. Yet, Hayes (2000) argued that "it is not the Cascade Model *per se* that is the problem, but the manner in which it is often implemented" (p. 137). Hayes emphasised that to implement the model successfully, the following key criteria should be taken into consideration:

> the method of conducting the training must be experiential and reflective rather than transmissive; the training must be open to reinterpretation; rigid adherence to prescribed ways of working should not be expected; expertise must be diffused through the system as widely as possible, not concentrated at the top; a cross-section of stakeholders must be involved in the preparation of training materials; decentralisation of responsibilities within the cascade structure is desirable. (Hayes, 2000, p.138).

This paper contributes to the ongoing concern about the effectiveness of the Cascade Model by reporting on a large-scale PD program aimed at improving teachers' content knowledge in disadvantaged communities. It provides empirical evidence to enlighten mathematics educators on the relevance of lesson design as a key tool to enhance the effectiveness of PD in practice. In particular, the PD model focused on the improvement of the quality of mathematics teaching and learning by simultaneously empowering teachers to develop effective learning resources and enhancing their content knowledge (CK).

The PD Model

The PD model (see Figure 1) was developed in the context of a Department of Foreign Affairs and Trade-funded project for large scale professional development in disadvantaged communities in West Nusa Tenggara (NTB), Indonesia. NTB is one of Indonesia's 34 provinces and is located in the eastern part of the archipelago. Made up of two islands, Lombok, with the capital city of Mataram, and Sumbawa. NTB is further divided into 10 districts (*kabupaten*). From 2011 to 2016, NTB fell in the lower 15th percentile of Indonesia's 35 provinces under the Human Development Index (Statistics Indonesia, 2018). NTB is a disadvantaged region in terms of economy, health and education.

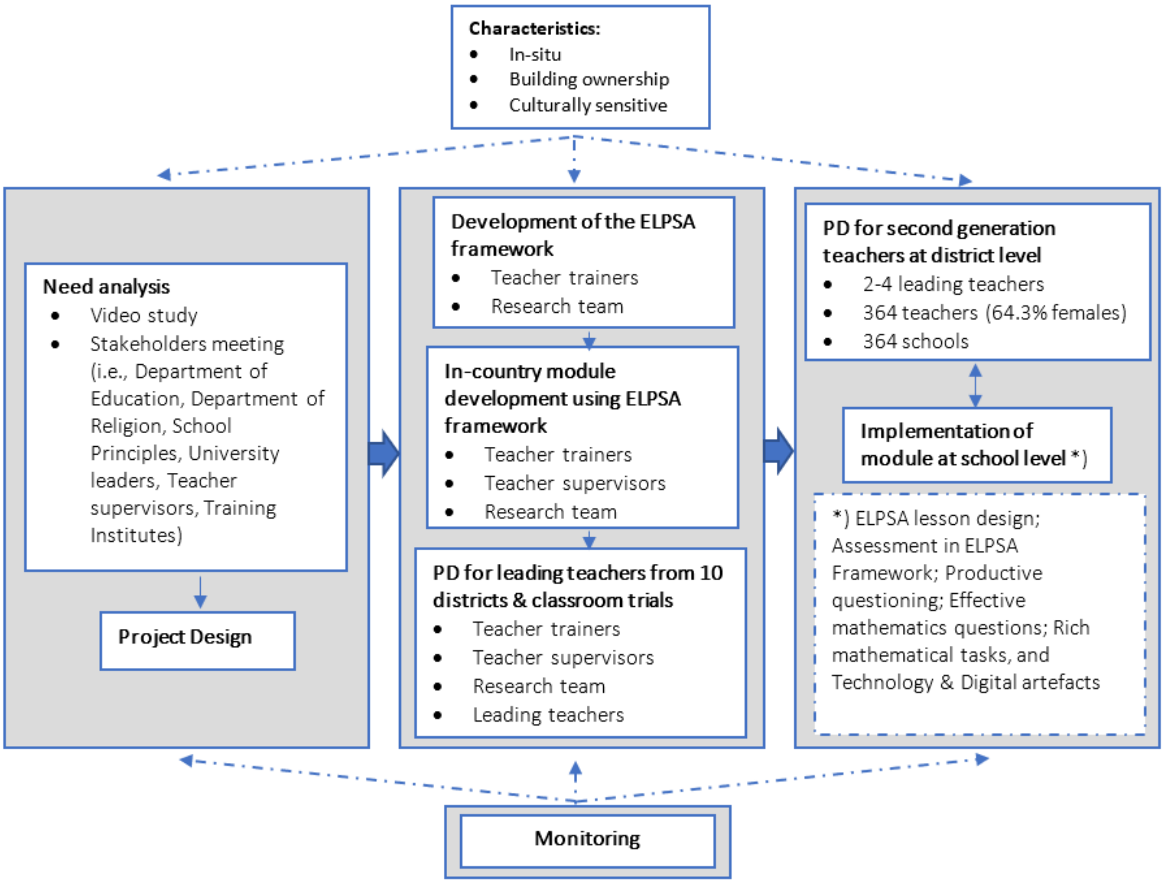

Figure 1. Professional development model

The PD model was developed to address multiple learning goals including enhancing teachers' mathematics and pedagogical content knowledge, developing their ability to design mathematics lessons using the Experience-Language-Pictorial-Symbolic-Application (ELPSA) framework (Lowrie, Logan, & Patahuddin, 2018; Lowrie & Patahuddin, 2015), and promoting reflective teaching through presenting and analysing their own or other teacher's teaching videos. This model involved leading teachers facilitating their peers in their own districts, guided by PD lesson design packages that were developed by the leading teachers in collaboration with mathematics teacher educators in NTB and from an Australian University research team.

The model involves several iterative phases: needs analysis; project design; development of teaching-learning resources; empowerment of teacher educators/trainers and leading teachers; trialling and implementation of materials in classrooms as well as ongoing monitoring and evaluation. The needs analysis requires that all the key stakeholders (e.g., Department of Education, school principals, teacher educators, teacher supervisors and teachers) are involved in the design of the project. The model is developmental and dynamic in nature to address emerging needs. The PD approach ensures that teachers are actively involved in the development of the materials for maximising ownership. It requires collaborative work in the development of resources to promote a sharing of knowledge and experiences. Much emphasis is placed on the connection between teachers' learning from the PD program and their in-situ teaching practice to experience the relevance, usefulness and value of the materials. Teachers are given extensive exposure to lesson design using the ELPSA framework (Lowrie, Logan, & Patahuddin, 2018), trialling, implementing, reflecting and refining their designs so that they can autonomously develop quality teaching materials, with rich learning tasks that promote student engagement. A brief summary of the ELPSA framework now follows.

The Experience (E) stage involves activities such as brainstorming and discussions around the mathematical concepts to be developed in a lesson. This initial stage audits what learners know as pre-requisites, starting from their lived experiences. The language of mathematics is critical in the process of concept formation. Thus, the ELPSA framework puts much emphasis on mathematical language (L) in conveying meaning and sense-making. This framework also pays much attention to the representations used by teachers and students. Pictorial (P), written inscriptions as well as mental models are helpful to scaffold students' understanding and to provide stimulus to complete mathematical tasks before the introduction of the symbolic notation. The fourth component of the learning design is concerned with the use of symbols (S) to represent mathematical ideas. Often the learning of mathematics is reduced to symbolic manipulations devoid of much sense-making which may lead to misconceptions. By focusing on the symbolic dimension, the ELPSA framework creates buffers that can minimise mathematical distortions. The last component of the framework is concerned with the applications (A) of learned concepts to new situations within the domain of mathematics as well as across disciplines. This component of the model enables teachers to add breadth and depth to students' understanding. The Application component may eventually become an Experience component in their next phase of learning, thus producing a cyclical dynamism.

The ELPSA learning framework was chosen as the vehicle to engage both teachers and students in the teaching and learning of mathematics as the needs analysis revealed that one of the major gaps in the school mathematics culture in the targeted Indonesian province was the lack of student engagement. The PD was crafted in terms of ELPSA-informed lesson design rather than conventional presentations and activities by mathematics educators or experts. In other words, in the PD workshops, teachers were required to design lessons according to the ELPSA principles that they would later implement in their respective classes. They were first required to collectively unpack the mathematics content that they routinely teach at school in Year 8 Algebra, Measurement and Geometry in line with the focus of the project. Then the ELPSA framework served as the guide to design the lessons, where teachers were required to rethink their teaching trajectory. In addition, they were motivated to consider other related issues such as the type of rich tasks that can be posed and students' misconceptions.

In this paper, we report on the effectiveness of one aspect of the PD, namely how the structure and operation of the PD model through lesson design enabled second-generation teachers to enhance their content knowledge in mathematics. The ELPSA framework that was used to design lessons during the PD provided affordances for teachers to strengthen their content knowledge

Methods

The PD program was conducted across two 15-week periods (3 hours/week) over a school year (or in total 30 weeks). Fifty percent of the program was undertaken face-to-face in Teacher Working Groups known as MGMP[1]. The other fifty percent was the implementation of the MGMP learning in teachers' own classrooms. A pre-post experimental research design was used to investigate the change in teacher CK after their participation in the 30-week training program.

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[1] MGMP is a Teacher Working Group consisting of secondary school teachers (Grade 7-9) in Indonesia, officially mandated by the Ministry of Education

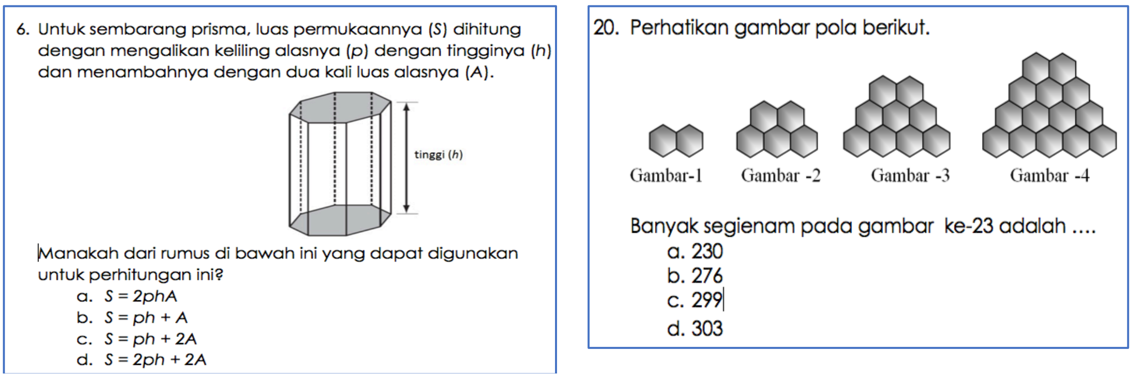
Participants

The participants of the study included 191 (128 female and 63 male) middle school teachers (Years 7– 9) from ten districts in the NTB province in East Indonesia. All of the teachers in this study had at least a 4-year undergraduate degree in mathematics education, with teaching experience ranging from 2 to 15 years. Teachers were selected from two categories of junior high schools. The first, called SMP, fell under the administration of the Ministry of National Education, and the second, Madrasah schools (called MTs) fell under the administration of the Ministry of Religious Affairs. In general, MTs teachers are recognised as having lower mathematics content knowledge due to less opportunity to join teacher professional development programs. In addition, MTs schools tend to place more emphasis on the learning of religion than mathematics.

A total of 364 mathematics teachers from 364 secondary schools across 10 districts in NTB participated in the MGMP. For the purpose of this project, groups of 25 teachers were formed in each district involving a representative proportion of SMP and MTs teachers. However, not all teachers were able to participate in both the pre- and post-testing. Some of the participants started the program late and some others did not attend the last session that included the post-test. Therefore, only 191 teachers who completed both the pre- and post-tests were included in the analysis.

Measurement of Teachers' CK

Teachers' content knowledge was assessed through a 25-item questionnaire (see Figure 2 for sample items) encompassing the following strands (Number, Algebra, Geometry, Measurement, Probability and Statistics).


6. Untuk sembarang prisma, luas permukaannya (S) dihitung dengan mengalikan keliling alasnya (p) dengan tingginya (h) dan menambahnya dengan dua kali luas alasnya (A).

Manakah dari rumus di bawah ini yang dapat digunakan untuk perhitungan ini?

a. $S = 2phA$
b. $S = ph + A$
c. $S = ph + 2A$
d. $S = 2ph + 2A$

20. Perhatikan gambar pola berikut.

Banyak segienam pada gambar ke-23 adalah ....

a. 230
b. 276
c. 299
d. 303

Figure 2. Sample items – Geometry stand (left) and Algebra strand (right).

Some of the multiple-choice items were adapted from existing teacher knowledge questionnaires. A correct item was marked as one. The questionnaire had a reliability (Cronbach's Alpha) of 0.8, indicating relatively high consistency.

Data Analysis

Results from the pre- and post-test questionnaire were analysed using paired sample t-tests to determine growth in CK between the SMP and MT teachers.

Results and Discussion

Table 1 shows that both Pre-CK and Post-CK scores of the SMP teachers were higher than MTs teachers. It is only after the intervention that the MTs teachers' content knowledge (mean = 16.0) were comparable to the SMP pre-CK knowledge (mean = 16.1). Table 1 also shows that there were statistically significant differences between pre and post CK for both SMP and MTs teachers. During the 30-week intervention, the PD model brought a significant increase in CK with medium effect size, d = 0.4 for SMP and d = 0.6 for MTs, as reflected in Figure 3.

Table 1
Descriptive statistics

School type	N	Mean (SD) - 25 items		t-test
		Pre-CK	Post-CK	
SMP	129	16.1 (4.29)	17.2 (4.23)	$t(128)= 4.88, p < .001$
MTs	62	13.1 (4.94)	16.0 (4.95)	$t(61)= 6.24, p < .001$

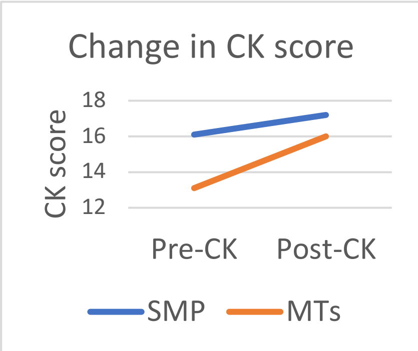


Figure 3. Pre-post CK improvement of SMP and MTs teachers.

The study aimed to understand how the lesson design-oriented PD model worked in practice as the vehicle to enhance teachers' content knowledge. Given that the PD took place through the process of lesson design rather than the explicit teaching of mathematics content, the improvement in the teachers' CK is a direct result of engagement with the ELPSA framework and unpacking the routine curriculum content. In the Experience phase, teachers were engaged in identifying the pre-requisite knowledge required for particular topics to immerse in the content, probing them to question their understanding of mathematical concepts. For example, when asked *What is the meaning of area?*, it was customary to provide a formulaic answer, rather than the meaning of area as the amount of coverage in terms of unit squares. In challenging teachers to design lessons that would allow their students to make sense of mathematical ideas, teachers were prompted to explain mathematical ideas in multiple representations (Language, Pictorial and Symbolic), thus reinforcing their content knowledge and pedagogical content knowledge. Teachers were encouraged to develop tasks and such a problem-posing exercise allowed them to engage with mathematical concepts with greater depth in contrast to their routine teaching that was often driven by textbooks through drill and practice (Human Development Department East Asia and Pacific Region, 2010). In summary, throughout the PD, teachers were given plenty of opportunities to rethink their taken-for-granted understanding of mathematical concepts in the lesson design process.

While we take the increase in CK scores as a marker of the effectiveness of the PD, we were challenged to sustain the endeavour for the prolonged duration (30 weeks). The initial timeframe of the project for the second-generation teachers was for a duration of 15 weeks.

We extended this to 30 weeks to provide the participants more time to unpack some of the materials such as the rich mathematical tasks. Given that we worked in remote areas and with a relatively large group of teachers (364) from a geographically diverse region, it was often difficult to get the participating teachers together in one place and at one point in time. The foregoing difficulty was minimised through the Cascade Model that empowered the leading teachers to in turn facilitate the implementation of the PD. To encourage teachers working in the disadvantaged region to participate, financial support was provided for transport and meal allowances.

Concluding Comments

This study shows that the Cascade Model of professional development can be rendered effective through lesson design, offering more opportunities to engage teachers as they revisit their teaching practice. In unpacking the content that they routinely teach in the lesson design process, they are given opportunities for reflection as well as knowledge reconstruction. Importantly, as they are themselves involved in the process of designing the lessons, and they take greater ownership of the developed resources. The participating teachers valued the resources developed as these were aligned to their curriculum and such materials were not regarded as extra work for them. Furthermore, given that they were from disadvantaged communities, the PD was taken as an opportunity for professional growth. The PD model aimed to influence the teaching practices of teachers who had limited resources and often relied on teacher-centred approaches with an emphasis on drill and practice, driven by the textbook. The model proved to work effectively in enhancing teachers' CK even though mathematics was not explicitly taught but rather emerged as a by-product during the 30-week intervention period. This study also suggests that the ELPSA Framework is not only useful as a tool to develop mathematics lessons for students as described in other papers (e.g., Patahuddin et al., 2018; Patahuddin, Puteri, Lowrie, Logan, & Rika, 2017), but can be a powerful model to promote mathematics content knowledge that enriches teachers' current practice. It involves teachers engaging with new pedagogical practices with a mathematical content focus. The effectiveness of the PD model can also be accounted by the way we integrated the consensus features of effective professional development (Garet, Porter, Desimone, Birman, & Yoon, 2001) in our project. Firstly, the PD was modelled explicitly on the needs of teachers with a content focus on mathematics teaching and learning sensitive to the Indonesian context. Secondly, the project team continuously supported the teachers, ensuring that we attended to their needs and responded to their challenges in the disadvantaged region where they were working. This level of support is important for developing teacher efficacy in new teaching practices. Thirdly, as part of the project monitoring mechanism, the research team conducted continuous assessment of field implementation to ensure that teachers were meeting the set target. Furthermore, the PD sessions lasted for a prolonged period of time, about 30 weeks. Although we experienced much success with the PD model, questions about sustainability and scalability are still open, especially in a relatively large country like Indonesia. However, the Cascade Model discussed here promotes sustainability as the ELPSA framework can be used in an ongoing way with new mathematics content as teacher confidence increases.

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References

Bett, H. K. (2016). The cascade model of teachers' continuing professional development in Kenya: A time for change? *Cogent Education, 3*(1), 1139439.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3-15.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945.

Hayes, D. (2000). Cascade training and teachers' professional development. *ELT journal, 54*(2), 135-145.

Human Development Department East Asia and Pacific Region. (2010). *Inside Indonesia's mathematics classrooms: A TIMSS video study of teaching practices and student achievement (Report No. 54936)*. Jakarta, Indonesia: The World Bank Office Jakarta.

Karalis, T. (2016). Cascade approach to training: Theoretical issues and practical applications in non-formal education. *Journal of Education & Social Policy, 3*(2), 104-108.

Krainer, K. (2015). Reflections on the increasing relevance of large-scale professional development. *ZDM, 47*(1), 143-151.

Lowrie, T., & Patahuddin, S. M. (2015). ELPSA as a lesson design framework. *Journal on Mathematics Education, 6*(2), 77-92.

Lowrie, T., Logan, T., & Patahuddin, S. M. (2018). A learning design for developing mathematics understanding: The ELPSA framework. *Australian Mathematics Teacher, 74*(4), 26-31.

Maass, K., & Engeln, K. (2018). Impact of professional development involving modelling on teachers and their teaching. *ZDM, 50*(1-2), 273-285.

Ono, Y., & Ferreira, J. (2010). A case study of continuing teacher professional development through lesson study in South Africa. *South African Journal of Education, 30*(1).

Patahuddin, S. M., Puteri, I., Lowrie, T., Logan, T., & Rika, B. (2017). Capturing student mathematical engagement through differently enacted classroom practices: applying a modification of Watson's analytical tool. *International Journal of Mathematical Education in Science and Technology, 49*(3), 384-400.

Roesken-Winter, B., Hoyles, C., & Blömeke, S. (2015). Evidence-based CPD: Scaling up sustainable interventions. *ZDM, 47*(1), 1-12.

Sifuna, D. N., & Kaime, J. G. (2007). The effect of in-service education and training (INSET) programmes in mathematics and science on classroom interaction: a case study of primary and secondary schools in Kenya. *Africa Education Review, 4*(1), 104-126.

Statistics Indonesia. (2018). Human Development Indices by Province, 2010-2017 (New Method). Retrieved from https://www.bps.go.id/linkTableDinamis/view/id/1211.

Sztajn, P. (2011). Standards for reporting mathematics professional development in research studies. *Journal for Research in Mathematics Education, 42*(3), 220-236.

Zehetmeier, S., & Krainer, K. (2011). Ways of promoting the sustainability of mathematics teachers' professional development. *ZDM, 43*(6-7), 875-887.