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Multi-level Scaffolding: A Novel Approach of Physics Teacher Development Program for Promoting Content Knowledge Mastery

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Global assessment of teacher’s competence in Indonesia illustrated that the teacher's professional development program (TPD) had not been effective in improving teacher quality, especially in the aspect of content knowledge (CK). This paper addresses the question of how to promote Physics teachers’ CK in science teacher education. The primary focus is on the knowledge transformation process. Mixed method design was used in this study to investigate the development of CK within a group of 45 high school Physics teachers who had at least 5 years of work experience teaching. The authors present a multi-level scaffolding (MLS) approach as a design heuristic for the in-service Physics Teacher Development Program (TPD) to further the principled design of these materials. They build from ideas about teacher learning and organise the heuristics around important parts of a teacher’s subject matter knowledge base. These heuristics provide a context for a theoretically oriented discussion of how features of TPD may promote teacher’s CK, by serving as cognitive tools that are situated in teachers’ practice. The authors explore challenges in the design of MLS approach, such as the tension between providing guidance and choice.

Key words: *Multilevel Scaffolding, Teacher Development Program, Content Knowledge, Physics.*

Introduction

Education is a timeless dimension to continue to be developed, not only because education covers a broad aspect, but also because education contributes greatly to the progress of a region and even the State — especially in the State of Indonesia. When talking about education, another related dimension is who is involved in the education process besides students. The definite answer certainly refers to the teacher, as the spearhead of the output of a learning process. The quality of education can be improved through improving several aspects (Jermsittiparsert, Sriyakul, Pamornmast, Rodboonsong, Boonprong, Sangperm, Pakvichai, Vipaporn, & Maneechote, 2016a, 2016b), one of which is improving the quality of teachers (Chonjo, 2018; Pugach & Peck, 2016; Hopkins, 2015). Teacher quality can be improved through various methods and strategies, including programs. Recent research has focused more on the topic of improving teacher quality through the teacher development program (TPD) (Ferrer& Poole, 2018; Kennedy, 2016; Jensen, Sonnemann, Roberts-Hull, & Hunter, 2016). In Indonesia, there has also been significant research on teacher program development professional development as a means of improving the quality of teachers (Rochintaniawati, Widodo, Riandi, & Herlina, 2018; Soebari & Aldridge, 2016; Rahman, Abdurrahman, Kadaryanto, & Rusminto, 2015). The designated local government or training institution had designed and implemented teacher professional development programs for more than a decade. Such programs include teacher certification programs and some forms of training. However, these programs have not shown a significant increase in teacher competency. The results of the World Bank study confirmed that one of the competency weaknesses of Indonesian teachers is in aspects of subject matter knowledge (CK) (Chang, Shaeffer, Al-Sammarrai, Ragatz, de Ree, & Stevenson, 2014). Policy makers and school systems have paid great attention to the problem of teacher knowledge about content and practices that are determined and embedded in the professional standards of teachers (Santoro, Reid, Mayer, & Singh, 2012).

The level of teacher knowledge is measured through the teacher competency test held by the government. The exam is carried out by testing professional and pedagogical competencies. The Ministry of Education and Culture confirmed that the results of the national competency test (the term in Indonesia is *Uji Kompetensi Guru/UKG*) in the last three years since 2015, still had problems with content knowledge (CK) despite having significantly increased the value that occurred in 2016. In fact, the average number until 2017 was still below 70, for all levels of primary and secondary education (Kemendikbud, 2017). More interesting data to describe the CK of teachers in Indonesia were the results of UKG scores above 60. In elementary school levels were 50.68% of the total number of teachers, 31.62% for Primary Schools, 43.84% for Junior High Schools, 53.55% for Senior High Schools, 44.53% for Vocational High Schools, and 42.19% for inclusive schools. This data illustrated the achievement of teachers' cognitive abilities in terms of professional and pedagogical knowledge. This data showed no more than half of our teachers scored less than 60, even though teachers were expected to score at least 70 in this competency test — which was the minimum CK score for teachers as determined by the National Board of Human Resource Development (Prihono, 2014). The data above becomes a joint evaluation for both teachers and policy makers. This means that the teacher's professional development program (TPD) had not been effective in improving teacher quality, especially in the aspect of CK. The findings we obtained in the field lead to the conclusion that teachers had the skills to apply the knowledge through the learning process, but the biggest obstacle was the limited mastery of the content knowledge of Physics teacher. This certainly had an impact on the achievement of student learning outcomes. Meanwhile, the teacher's professional development program was still in the form of training and workshops that had not continuously carried out.

The research we conducted in 2015 in Rahman, Abdurrahman, Kadaryanto, & Rusminto (2015), succeeded in investigating TPD that could improve teacher CK, which was called teacher-based scaffolding (TBS). TBS has been proven to significantly increase the level of ownership of Indonesian teachers. However, the weakness of TBS is in terms of program continuity. FFB had not been able to be applied continuously, so there was no follow-up after obtaining an increase in CK. In addition, the TBS program only provided treatment directly from experts to practitioners or teachers, there was no intermediary between them. The researchers' concern was that if the number of experts is limited and TBS was not applied regularly by experts, then perhaps the achievement of the teacher by the teacher will return to the initial stage where the teacher's level was still low. The role of experts on TBS was very urgent. If the teacher learned material from someone who had not mastered the content and was not done routinely, then the treatment provided by the expert will not be optimal. Whereas CK acts as the basis needed for effective teaching (Chan & Yung, 2018; Tchoshanov, Cruz, Huereca, Shakirova, Shakirova, & Ibragimova, 2017; Loewenberg Ball, Thames, & Phelps, 2008; Shulman, 1987). Therefore, the research we were conducting is developing the TBS program into a cyclical program, to enable follow-up of each achievement of teacher’s CK and provide opportunities for teachers to play a greater role in it. Even though the government has not implemented TBS as a professional TPD in Indonesia, we continue to improve TBS as an alternative solution to the problem of education in Indonesia.

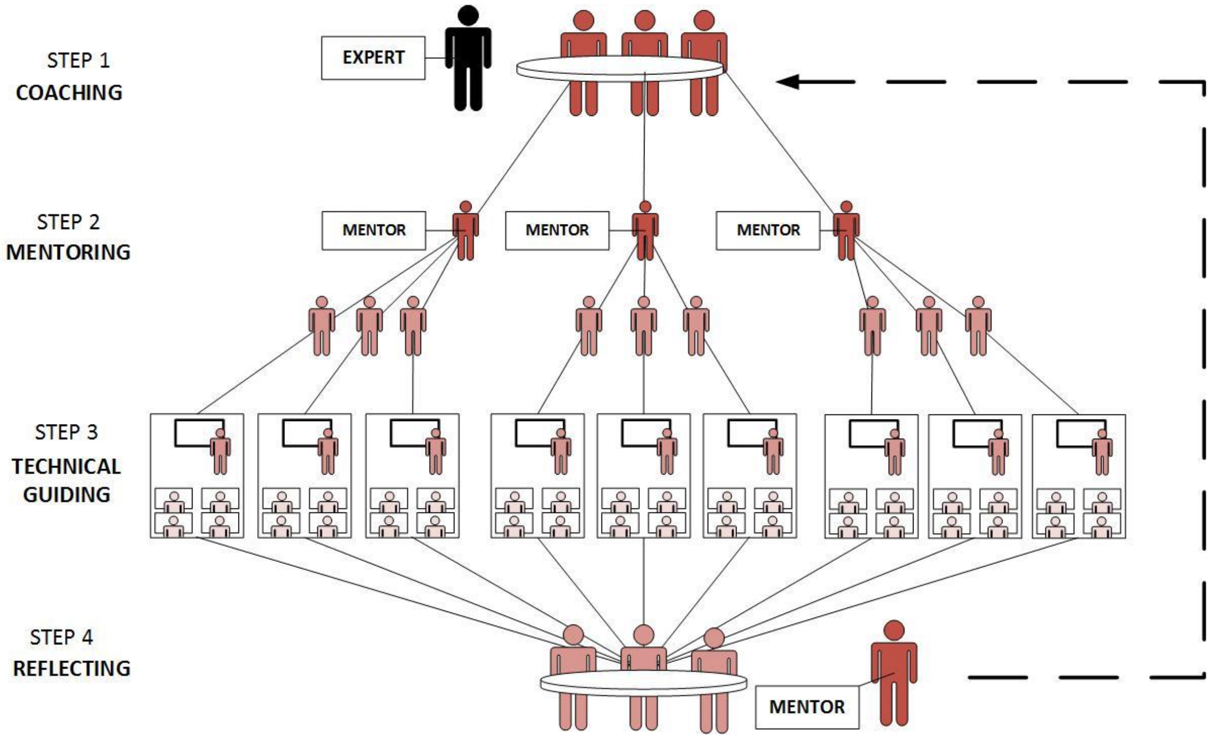
Our research referred to conditions, needs, and expectations not only from teachers, but also from professionals (Boud & Hager 2012; Chval et. al, 2008; Grant, 2002; Lee, 2005). In this paper, we explained the implementation of an MLS-based TPD program that we had previously designed and evaluated to continually improve teacher CK in Indonesia. The research we previously conducted (Rahman, Abdurrahman, Kadaryanto, & Rusminto, 2015) had presented the contribution of scaffolding in the teacher's professional development program. In addition, another study conducted by Koh, Chai, & Lim (2015) also described the contribution and importance of scaffolding in supporting teachers' professional development programs related to 21st century learning. They applied scaffold targets, social scaffolds, and process scaffolds in research, and they stated that the scaffolding they apply could support the process of developing teacher professionalism. In fact, the application of scaffolding in teacher professional development could have an impact on teacher motivation in teaching, teaching practice, and student achievement (Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller, 2016; Nurulsari, Abdurrahman, & Suyatna, 2017). Therefore, scaffolding could undoubtedly contribute to the improvement not only of teachers, but of motivation, performance and student learning outcomes through TPD. However, research on the development of scaffolding itself in the realm of the TPD program was still very minimal. The concept of the program we offer in this study remains oriented towards scaffolding, but we have developed it into multi-level scaffolding. We see scaffolding not only as a program, but we see the application of scaffolding as a great potential to solve educational problems in developing countries such as Indonesia, especially in increasing the number of teachers in Indonesia.

Method

Subjects

In this study, we focused the research subject on Physics teachers in Metro District, Lampung Province, Indonesia. We used purposive sampling techniques; we chose to sample only teachers who scored below the standard score of *UKG national test standard*. We decided to take a sample of the Physics teachers because the highest percentage of scores below the standard score on the teacher competency test was Physics teachers. The sample in this study was 45 high school Physics teachers who had at least five years of work experience teaching. All these samples were given treatment through the application of a multi-level scaffolding (MLS)-Based TPD program that we developed. Most of the mentors involved were senior teachers who have more than 10 years of learning experience and a passion in developing creative and innovative learning. We prepared 15 mentors who were responsible for and guided three teachers each. Meanwhile, all experts were determined based on expertise that had a minimum doctoral education level in the field of Physics Education and Science. The MLS model was applied for four months with three MLS cycles. In contrast to the concept of the TPD program that we have developed before, in this paper we use the concept of MLS as an effort to increase teacher level through the TPD program. The MLS-based TPD program offered a new concept of a sustainable TPD. It involved not only teachers, but also experts and mentors. The MLS-based TPD program is illustrated in Figure 1.

Figure 1. MLS-Based TPD Program



Data Collection

The data for the teachers' competence on content mastery was collected before and after with a multiple-choice test of national teacher competency test questions. We collected the pre-test data after the implementation the TPD program that we developed in four months. Since the instruments used in the pre-test and post-test of the TPD program were taken from a national teacher competency test, it was assumed that the instruments were valid.

Data Analysis

The reliability of the instrument used was calculated using Pearson-Product Moment Correlation Coefficient (r). The scores of pre-test and post-test were analysed using paired sample t test to describe the improvement in the teacher's content knowledge with the significant level set at alpha 0.05. We also conducted the gain analysis Hake (2001) to describe the effectiveness of the TPD program that we developed.

Result and Discussion

As illustrated in Figure 1, the treatment given to the teacher was not directly conveyed by experts but must first go through a mentor. So, experts, mentors, and teachers were not the same person, but it did not rule out the possibility if the teacher meets the qualifications as a mentor. People who will be appointed as experts were people with extensive knowledge or abilities based on research, experience, or work in the fields of Physics and educational Physics (Bogner, Littig, & Menz, 2009). Unlike experts, mentors were trusted as tutors, facilitators, and advisors. A person who was appointed as a mentor was someone who was willing to spend their time and expertise to guide the development of Physics teachers, particularly to increase CK in the field (Haggard, Dougherty, Turban, & Wilbanks, 2011).

The MLS-based TPD program was developed based on theoretical and empirical rationality. Every stage in the program that we have developed was designed so that each phase can contribute to the development of the teacher. The steps in the MLS scaffolding model are summarised in Table 1.

Table 1: MLS Model Descriptions

No	Steps	Period Length	Descriptions
1	Coaching	One month (four face-to-face meetings)	In this model, coaching at this stage was interpreted as an activity where the experts train the mentors so that the mentor will be able to assist the teachers in exploring their content knowledge and learning new instructional strategies in the context of their own schools and classrooms (Pitsoe & Letseka, 2014). Coaching in this phase refers to ongoing long-term training activities, assistance, and evaluations carried out by an expert (Mohammadi & Mortazavi, 2019). At the coaching stage, the mentor is given the opportunity to work collaboratively with fellow mentors in relation to problems based on their daily work with students (Charner-Laird, 2007). In other words, the coaching stage is mentoring the mentors (Shimi & Boath, 2018). The practice and real experience of a mentor in teaching in class provides data as material for discussion between experts and the mentors. Mentors are provided with material by experts so that mentors first learn and explore content knowledge in teaching and integrate new teaching strategies into their teaching.
2	Mentoring	One month (four face-to-face meetings)	The mentoring stage in this strategy aids (Wildman et al., 1992) teachers who played a role at the next stage as Physics teachers, where mentors and teachers focus on discussing teaching principles and basic and integrated forms of class communication. Activities at the mentoring

			stage are oriented to four components: providing emotional and psychosocial support for learning; supporting the construction of teachers' practical knowledge of teaching; creating a favourable context for teacher learning; and change the teacher's negative behaviour toward positive behaviour (van Ginkel et al., 2016). The mentors must manage the relationship, encourage the mentee, nurture the mentee, teach the mentee, offer mutual respect, and respond to the mentee's needs (Asuo-Baffour et al., 2019). Broadly speaking, mentor activity is to open interactions, facilitate, provide counselling, guide and lead (Heikkinen et al., 2018). This stage is developed to cover other aspects for effective teaching, including how to deliver content knowledge (Hudson, 2013).
3	Technical Guiding	Two months (eight face-to-face classroom activities)	The technical guiding referred to in this stage involves the teacher practising based on the results of the mentoring or training obtained in the previous stage, in the form of teaching in the classroom. Therefore, the teacher not only mastered the theory, but the teacher also mastered how to deliver the content to students. Technical guiding at this stage is not an activity where participants are given training that is useful in improving teacher competency, but a form of practice of the mentoring results obtained while still within the supervision of the mentor. Thus, through practice in the classroom, the teacher will find technical obstacles.
4	Reflecting	One week (two meetings)	Reflection at this stage is a component of activities carried out by teachers and mentors after teaching practice in the previous stage, with the aim of reviewing what has occurred during the practice of learning. This stage is conducted to consider what else needs to be learned to improve teacher content knowledge which can then expand to the area of the interdisciplinary project (Morselli, 2019). Reflecting activities are a form of opportunity for teachers to reflect on and articulate their learning experiences related to teaching practices, and to share and discuss them with mentors (Sandoff et al, 2018). The reflection phase leads to a level of improvement that depends on the extent of the comments and suggestions of the mentors and peers (Franz et al., 2018).

The MLS-based TPD program covers several topics that extend from aspects of the teacher's content knowledge that are investigated. This includes innovative learning strategies, class management, student involvement, technology utilisation, student worksheets and assessment instruments involving all levels of experts, mentors, and teachers at each stage and topic as outlined in Table 2.

Table 2: MLS Model Implementation Content Analysis

No.	**Discussed Topic**	**Phase in MLS TPD Program**			
		Coaching	**Mentoring**	**Technical Guiding**	**Reflecting**
1	• Essential Physics Concept • Concept Map • Misconceptions	√	√	√	√
2	• Classroom management • Appropriate Teaching Strategies	√	√	√	√
3	HOTS Assessment Instruments	√	√	√	√
4	Student Engagement	√	√	√	√
5	• Learning Media with Digital Technology • Student Worksheet	√	√	√	√

The feasibility of the MLS-based TPD program was tested by analysing the improvement of teachers' content knowledge in Physics based on pre-test and post-test scores using the instruments provided. Since the instruments used in the pre-test and post-test of the TPD program were taken from a national teacher competency test, it was assumed that the instruments were valid. Then, we tested the reliability of the instrument, and the test results showed the value of Cronbach's Alpha which is 0.512, which means that each item was reliable in the medium category. Based on the results of the normality test, the whole group of data were normally distributed and homogeneous with a significance value >0.05. The descriptive statistics analysis was represented in Table 3. Then, we analysed the pre-test and post-test scores using the paired sample t test technique, and the results of the analysis are presented in Table 4.

Table 3: Descriptive Statistics Analysis Results.

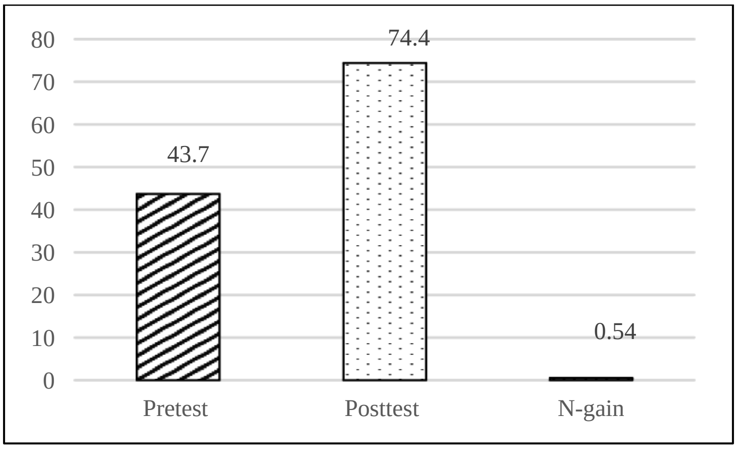
	N	Minimum	Maximum	Mean	Std. Deviation
Pre-test	45	24.00	64.00	43.71	10.78
Post-test	45	64.00	84.00	74.44	5.42
Valid N (listwise)	45				

Table 4: Paired Sample t-Test Analysis Results

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test Post-test Results	-30.7333	9.77567	1.45727	-33.67027	-27.79640	-21.090	44	.000

Table 4 showed that there was a significant increase in teacher's content knowledge between before and after the implementation of the MLS-based TPD program. This was indicated by a significance value of <0.05. That is, the application of the MLS-based TPD program had an influence on the mastery of content knowledge by Physics teachers. This result was supported by the results of the N-gain analysis which can be seen in Figure 1. Based on Figure 2, it is seen that the MLS-based TPD model is effective in increasing teacher CK in the medium category.

Figure 2. N-gain Analysis Results



The success of increasing teacher CK was attributed to MLS featuring a soft scaffolding approach that enables teachers to develop and improve mastery of concepts and Physics content (Niess, 2018; Smit et al., 2018; van Driel et al., 2019). Therein, any difficulties faced by teachers in mastering concepts and Physics content did not stop at the teacher, but will be followed up and resolved at the stages in the MLS model, so that teachers become motivated to improve (Kiran et al., 2019; Kuo et al., 2019; Vedder-Weiss & Fortus, 2018). The MLS model is not a conventional or short-term TPD training (Spatz et al., 2019), but continuous and directed training. This model enables the TPD program development goals to be well-achieved (Özer et al., 2019), especially in the CK aspects of the teacher.

Based on the results of individual interviews, teachers felt they had benefited and being helped by the MLS program. They revealed that their failure to achieve maximum scores in the UKG test was because every problem they faced — especially related to Physics content — had never been resolved, resulting in the problems piling up without any follow-up. Arguably, this affects the UKG results. However, with the MLS program, they were very enthusiastic because they felt the difficulties they faced regarding mastery of the concept could be overcome; it aroused their motivation to learn. They stated that every difficulty they faced at the technical guiding stage was immediately followed up at the reflecting stage, directly from the mentor to the teacher, without requiring a long period of time. Then, the mentors also stated that they were confident to guide Physics teachers because the experts had provided them with enough knowledge at the coaching stage. The knowledge that mentors obtained was not only on Physics content knowledge but included how to manage learning effectively and efficiently. The mentors stated that if they had difficulty in the mentoring and reflecting stage, they immediately obtained alternative solutions and problem solving in the face of teachers who were experiencing difficulties.

On the other hand, from the observations in the study, there are several factors that need to be considered regarding management in a learning model. Effective management is the result of several factors; there are no simple blueprints or guidelines for effective classroom management. The teacher must determine the needs of students by developing a management system for daily living to the personality needs of children who are expected to interact with certain achievements (Sagala et al., 2019). Effective management encourages student success. The function of good management is as a means of connecting the strength of students to a productive learning experience and if students learn efficiently, the teacher will try to achieve achievement in weak classroom management (Syazali et al., 2019).

Success increases appreciation for students, if students perform well. There is a result of feeling satisfied, then self-esteem and drive for achievement are getting higher (Ye, 2017). Free and unlimited effective management. Many teachers believe that if management is too structured, it reduces student creativity. However, effective management provides students with clear, working guidelines. This situation creates work patterns that are consistent and free from confusion and discipline and that are less structured to produce their full creativity (Syazali et al., 2019).

Management effectiveness is consistent. Teachers must work in the same way, for the same expression of wrong behaviour. Teachers should not punish with anger or despair. Of course, teachers should not be afraid to be angry if anger does not reduce the motivation and punishment given (Syazali, 2015). Effective management involves attention and development of innovation. It should appear to students that management is carried out by the teacher to nurture student learning and develop innovative teaching activities. Management problems may not appreciate the quality of the teaching system. Effective management includes re-influences on desirable behaviour and reinforcement of desirable behaviour. Teachers are models of accepted behaviour. Obsessed learning should be modelled by teachers. Effective management demands teamwork from principals, teachers, parents, the community, and other education professionals who work consistently towards the same goals (Habibi et al., 2019).
The estuary of the functioning of good learning management is effective learning (Syahrir et al., 2018). That is, from the position of the teacher creating effective teaching, from the position of students creating effective learning (Ramadhani, Umam, Abdurrahman, & Syazali, 2019). According to Joyce and Weil, "A successful teacher is teaching students how to have information in a conversation and make it their own" (Thanomton, Niyamabha, Wichitputchraporn, & Koedsuwan, 2018). Whereas "effective learners are forming information, ideas and wisdom from their teachers and using learning resources effectively" (Pompuang et al., 2019).

The main role in teaching is to create a model of strong teaching activities. Teaching activities as environmental management, classroom settings, in which students can interact and learn how to learn (Lestari et al., 2019).

Regarding the effectiveness of teaching, to achieve active learning, one important aspect is the problem of the method used by the teacher in creating an active atmosphere (Lixia, 2017). The learning process using the lecture method comprises the teacher dominating the conversation while students are forced to sit, listen and take notes; this is not recommended. The lecture method must be reduced, even abandoned (Hartinah et al., 2020).

The new paradigm in active student learning requires teachers to change their perspective on learning. In preparation for teaching, teachers think more or focus on creating new experiences for students (Diani et al., 2019). Through this experience, students can develop their knowledge. The teacher processes the right curriculum so that with the correct understanding of concepts formed by students, it is possible to connect them with previous understanding and open opportunities to seek and find understanding of new concepts (Diani et al., 2019).

Likewise, with the experts, they felt that the MLS-based TPD program was very efficient to improve the CK of Physics teachers. The experts stated that they had given training to Physics teachers directly (conventionally) for two to three days by delivering the material, then they tested the teachers with the pre-test and post-test questions that had been developed. Indeed, on that day there was a significant increase in CK teachers. However, when returning to school, the knowledge gained during the training related to mastery of the concept of Physics, they did not apply in learning. Thus, the low mastery of teacher content, not only had a direct impact on the teacher, but also has an impact on the emergence of many Physics misconceptions in students (Bautista & Ilie, 2019; Moodley & Gaigher, 2019; Smith, 2015). The experts stated that the MLS model was indeed different and very feasible to be implemented, because the concept of a soft scaffolding strategy was successfully packaged systematically enabling the stages of knowledge transfer to run continuously and effectively (Belland et al., 2015). Therefore, the experts felt aided in realising their vision and mission to fix the low achievement of CK Physics teachers. Conclusively, the teacher did not try alone to increase the CK owned but was supported by all parties who were in the same vision and mission.

Conclusion

The developed MLS-based TPD program was statistically proven to significantly improve CK Physics teachers, with the level of effectiveness in the medium category. The improvement of teacher CK was attributed to MLS consisting of a soft scaffolding approach that enables teachers to develop and improve mastery of concepts and Physics content. The approach achieves this through four stages: coaching, mentoring, technical guiding, and reflecting. Experts, mentors, and teachers all had duties and obligations in carrying out this program. The MLS model that we have developed has the potential to overcome the problem of low CK of Science Teachers in the global scope, and it requires further research. The MLS-based TPD Program model is a continuous program, thus minimising all the difficulties experienced by Physics teachers in learning more about Physics concepts and content.

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