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Innovative lesson study (LS) to improve the pedagogical content knowledge (PCK) of STEM teacher candidates in Indonesia

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ABSTRACT: Lesson study-based learning is the favourite method to teach teacher candidates of science, technology, engineering and mathematics (STEM), so as to enhance their teaching skills. Through research it was found there are obstacles to teaching STEM subjects at schools and to rectify them, some references recommend lesson study (LS) by content representation (CR) with support of a pedagogical and professional experience repertoire (PPER) to solve the problems. This could enhance the pedagogical content knowledge (PCK) of STEM teacher candidates. To achieve this, STEM teacher candidates would need to undertake an intricate process of teaching practice in classrooms. The aim of this article is to explain the representation of pedagogical content knowledge (PCK) in CR and PPER in the lesson study programmes in the subject *school internship* at the State University of Malang, Indonesia. There are five steps in this model, viz preparation, coaching, guided practices, independent practices and evaluation.

Keywords: Lesson study, STEM teacher candidates, pedagogical content knowledge, content representation

INTRODUCTION

The quality of education in Indonesia is generally considered to be low [1]. What is most important to improve education quality is to enhance the quality of the teachers. To this end, the Indonesian government has taken steps to improve training, such as offering scholarships to raise teachers' qualifications and carrying out competency assessments. Another approach is to improve the quality of teachers-to-be, while they are students in college [2]. This is a lengthy process since deep knowledge, including knowledge acquired through practice, and great skill is required to be a professional teacher [3-5].

Professional teachers have three kinds of knowledge: content knowledge (CK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK) [6][7]. Content knowledge is knowledge of an area or discipline, e.g. chemistry or physics. Pedagogical knowledge is knowledge of how to teach. Pedagogical content knowledge is knowledge of how to teach particular content in a way that makes it easier for students to understand [4][6][8][9]. Hence, PCK mostly affects learning practice and is an essential component in the professional development of teachers [10][11].

Pedagogical content knowledge serves as a repository of knowledge for teaching activities [4][10]. Pedagogical content knowledge is not an innate skill, but one that can be taught. To acquire this skill, teacher candidates need to go through a long process of teaching practice sessions [3].

It was found through Indonesian research that the targets for setting lesson plans have yet to be reached [12][13]. Zendrato opines that many teachers are unaware of the importance of lesson plans in the success of the learning process [14]. Teachers ought to set up lesson plans, so that the learning process achieves the learning objectives [15]. However, some teachers set up lesson plans by copying and pasting already existing lesson plans, simply to fulfil the administrative requirements [16]. They often use student handbooks as teaching guidelines, which does not necessarily meet the requirements of the curriculum or students' characteristics. This results from their lack of content knowledge when planning their learning activities [17].

Silaban's research shows that the quality of lesson plans is not yet satisfactory (68.18%) [18]. Passive teachers and students during learning is indicative of this unsatisfactory condition. Etkina indicates that teachers only repeat materials in the way they were taught [6]. An on-line test revealed the low competency of science, technology, engineering and

mathematics (STEM) teachers [19]. This is a consequence of teachers' lack of awareness in drawing up lesson plans and lack of mastery of teaching materials.

It is important that the problems discussed above be resolved soon. One of the suggested methods is to produce professional STEM teachers by giving PCK to teachers-to-be [6][7]. Pedagogical content knowledge is closely related to the depth of content knowledge, teaching experience and flexibility in adapting to changes [20][21].

Pedagogical content knowledge could be provided to STEM teachers-to-be by teaching them lesson planning and content representation (CR) at college. The study is aimed at developing an understanding of how lesson study (LS) can be planned, in colleges, with content representation (CR) and with a pedagogical and professional experience repertoire (PPER). This would form the basis of a model programme to improve the PCK for Indonesian STEM teachers-to-be.

LITERATURE REVIEW

Theoretical and empirical studies support the development of a model programme of LS with CR and PPER, to improve PCK skills of STEM teachers-to-be in Indonesia.

Table 1 shows that lesson study planning with content representation can be through experimental, qualitative, quantitative or mixed methods to improve STEM teacher candidates' pedagogical content knowledge (PCK). Data for this research were obtained from questionnaires, interviews, observation and documentation. The implementation of LS with CR and PPER determines the improvement of PCK.

Table 1: Research for LS planning with CR and PPER.

Quantitative research with questionnaires [21]. The use of CR to develop teachers' PCK at the beginning of their careers. It was designed to determine whether teachers-to-be under supervision of an expert could improve their PCK. The research showed that CR developed by this method could improve knowledge and pedagogy
Descriptive qualitative research using observation and interviews [22]. Provide curriculum with new learning activities. Investigate the effectiveness of the approach to improve teachers' knowledge and pedagogical practices. It is undertaken through implementing LS within a one-year academic term. Teachers are provided with a framework critically reflecting their teaching activities by their involvement as a member of a community of mathematics teachers in which they could be directly and actively involved in projects of a new mathematics curriculum. Lesson study results in the improvement of teachers' CK and PCK.
Qualitative research using a case study [23]. This research aims to build the teaching skills of teachers-to-be by developing PCK. Students are introduced to CR. This qualitative research is done through a case study carried out in workshops after students have taken part in teaching practice in schools. Students participate in a three-hour workshop to devise a CR for chemistry. This heightens their awareness of PCK components, such as knowledge of the curriculum and teaching strategies.
Qualitative research using questionnaires, interviews and documentation [24]. Explains how science teachers in elementary schools interpret, use and develop their understanding of global warming. Teachers develop an understanding of teaching practices, class assessment and CK regarding global warming. Therefore, teachers' CR could be used as a means of understanding PCK and its influence on science teaching.
Experimental research with a control group [25]. The purpose is to observe how CR and PPER could affect the teaching practices of science teachers by taking into account PCK as an integral part of their professional knowledge. This research is based on a two-year longitudinal study using CR and PPER as an intervention by the teacher group to know how they interpret, use and develop their understanding of PCK. Teachers develop their understanding of teaching, CR and PPER. This can also be used as a reliable method for assessing the PCK of science teachers.
Qualitative and quantitative research with written assignments, a journal of *written reflective* and the video recordings of lessons [26]. The purpose is to test teacher candidates' PCK concerning learning difficulties, learning strategies and the effect of using the developed model. This uses peer coaching-based comprehension, observation, practice and reflection (PCK-COPR). Data include written assignments, reflective journals and video clips of the learning activities. The research finding shows that teacher candidates clearly realise students' initial conceptions of a lesson and their learning difficulties. In addition, they also study the implementation of some teaching methods to stimulate knowledge integration. This model enables them to observe and learn from more experienced and better-trained mentors. Pedagogical content knowledge-COPR helps develop the PCK of teacher candidates, and is useful for other pedagogical purposes.

DISCUSSION

Nilsson and Loughran explored LS learning combined with CR and PPER to solve PCK problems for STEM teacher candidates in higher education [3]. Content representation depicts how teacher candidates see a particular content and how they understand the learning process. Besides, CR provides a framework useful for planning, organising and thinking of content.

Content representation indicates the content teachers consider important. Content representation is designed before the learning and serves as a reference in developing lesson plans and learning scenarios [27]. Teachers identify essential concepts and, then, develop relations to other concepts. Teachers must know which concepts to introduce and which concepts not to introduce.

The pedagogical and professional experience repertoire is a narration related to the implementation of a teacher's PCK focusing on particular aspects or content of the material being taught. The purpose of PPER is to provide teachers with fresh insights about specific aspects of PCK as an integral part of the teaching practice in class. It guides teachers to teach specific aspects of material content in learning activities. The building of PPER as a narrative is aimed at allowing teachers to understand and have a concept of the interaction of PCK components. The narrative can be instrumental in encouraging reflection on the PCK, leading to changes in teaching methods.

Each teacher candidate will have a different opinion and sources in building a PPER. These include student learning activities, teacher learning activities, interviews, observations in classes and reflections on the curriculum [28]. Consideration is given in this study to the PPER focused on how teachers see the learning process. Therefore, the PPER must be based on observation.

The categorisation of the components of a PPER by PCK concepts is shown in Table 2 [29]. The CR and PPER can be used to portray teacher candidates. Both are involved in PCK for STEM teacher candidates. The PPER can identify holistic and complex characteristics of PCK, which CR cannot.

Table 2: The mapping of PCK concepts to PPER components.

<table>
<tr><th>PCK concept</th><th>PPER component</th></tr>
<tr><td>STEM-teaching</td><td>To narrate perception and motivation, as well as cognitive conflicts.</td></tr>
<tr><td>Knowledge of the STEM curriculum</td><td rowspan="3">To narrate the main activities in the learning process, including: 1) observation; 2) addressing questions; 3) reasoning activities; 4) practising; 5) communication.
To narrate closing the learning activities, including: 1) reflective activities concerning concepts; 2) sharing factual knowledge and integration of concepts from daily life; 3) individual study club information.
Discussion materials for future meetings.</td></tr>
<tr><td>Knowledge of learning STEM</td></tr>
<tr><td>Knowledge of teaching strategies for STEM</td></tr>
<tr><td>Knowledge of STEM evaluation</td><td>To narrate evaluation.</td></tr>
</table>

Juhler combined lesson study with CR and PPER to develop the PCK of pre-service teachers. This combination can help pre-service teachers focus on observing all important elements in drawing up lesson plans [30]. It is the element of Magnusson et al that was called the important element [29]. Pedagogical content knowledge depends on the development of all-important elements of PCK. Lesson study generally develops and evolves through six stages; establish purpose, plan, observe and practice, discussion and improvement, repeat and disseminate.

STEM teacher candidates will be taught how to improve the LS in collaboration with CR and PPER as representative of PCK. This model is called the model of LS-CRPPER (lesson study with content representation and pedagogical and professional experience repertoire). This model can be implemented during school internships for STEM teacher candidates. It consists of five steps (see Figure 1):

1) Preparation;

2) Coaching;

3) Guided practice;

4) Independent practice;

5) Evaluation.

Phases	1. Preparation	2. Coaching		3. Guided practices		4. Independent practices		5. Evaluation
Location	Higher education	Higher education		Higher education and high school		High school		Higher education
LS-CRPPER process	• Briefing lesson activities in the school internship • Provision of a model for teacher-mentor • Studying a school's lesson plan	P	Establishing instructional objectives ↓ CR to concept maps ↓ Creating learning design (lesson plan, worksheet, and assessment)	P	Establishing instructional objectives ↓ CR to concept maps ↓ Creating learning design (lesson plan, worksheet, and assessment)	P	Establishing instructional objectives ↓ CR to concept maps ↓ Creating learning design (lesson plan, worksheet, and assessment)	• Evaluate the LS-CRPPER process • Evaluation of the LS-CRPPER result • Document the evaluation of LS-CRPPER
		P E	Presenting lesson design ↓ Reflection-revision	P E	Presenting lesson design ↓ Reflection	P E	Presenting lesson design ↓ Reflection	
		D & S	Doing peer teaching 1 ↓ Reflection-revision ↓ Doing peer teaching 2 ↓ Reflection-revision ↓ Develop PPER	D & S	Real teaching practice 1 ↓ Reflection-revision ↓ Real teaching practice 2 ↓ Reflection-revision ↓ Real teaching practice 3 ↓ Reflection-revision ↓ Develop PPER	D & S	Real teaching practice 1 ↓ Reflection-revision ↓ Real teaching practice 2 ↓ Reflection-revision ↓ Develop PPER	

Note: P = plan; PE = plan evaluation; D & S = do and see

Figure 1: The LS-CRPPER model for school internships in STEM teacher education.

The LS cycle is implemented in the coaching step. This cycle includes:

1) establishing purpose;

2) mapping concepts and completing the CR;

3) creating the learning design (lesson plan, worksheet, assessment);

4) presenting learning design or peer-reviewed teaching;

5) reflection-revision.

After revision, the cycle will continue by peer-reviewed teaching, reflection and revision, to refine the teaching. The result of LS with CR will be reported as part of PPER.

Lesson study in this model involves four steps, i.e. plan, plan evaluation, do or implement, and see or review. In the first step, *plan*, STEM teacher candidates collaborate in designing lesson plans, which includes establishing learning indicators and objectives, mapping concepts, designing CR, determining activities of students and teachers, setting student worksheets, choosing media and devising assessment instruments.

In the step, *plan evaluation*, teacher candidates present their designs to other groups and supervising teachers, for feedback and evaluation. Afterwards, they revise the design based on the feedback. The step, *do*, involves implementing the learning design by peer teaching using a three-person group - one serving as a model teacher, the other two as observers and students.

See is the step of reflection to evaluate the learning practices, particularly students' understanding and materials. To this point they have yet to face real students.

Phase 1: Preparation

The preparation phase took place in the STEM teacher education during the school internship I. It took ten working days to complete. It began with the introduction to the implementation of school internships I and II, explaining the urgency of participating in the briefing session for school internship I. In this session, all members were also asked to leave WhatsApp and email addresses, considering that both are used as a means of communication, discussion and handing in assignments.

On days 2 and 3, STEM teacher candidates were given a chance to visit a school to observe STEM teaching. Also, the teacher candidates receive information on their teaching schedules and the classrooms where they teach, as well as materials available for teaching in school internship II. In addition, the teacher candidates were given information about students' characteristics, sample syllabi, lesson plans, assessment system and available laboratory equipment and facilities.

Activities on day 4 were in college, where the teacher candidates presented a comprehensive review of the curriculum, particularly concerning process and assessment standards, and learning models. Raising issues concerning these provided a stimulus, to which they responded based on their previous experience [31][32].

According to Piaget, raising problems will assimilate new knowledge into similar existing knowledge. This will make it easier to directly address problems by referring to previous knowledge and experience. However, given the fact that each has their own experiences probably different from others, it is essential to initiate group discussions to focus and design materials to use in LS in school internship II.

Subsequently, each of the teacher candidates was assigned to design lesson plans to use in a two-hour teaching practice (90 minutes). This was done by studying lesson plans of schools that they had visited. In this assignment, they were to establish the purpose, map the concept, design the CR, and arrange the learning practice, process and assessment. This was set as homework to be handed in via email to their supervisors.

Phase 2: Coaching

On day 5, teacher candidates went through the phase of coaching, where supervisors explained CR and LS. They were asked to collaborate with each other, especially those engaged in the internship programme in the same school (three teacher candidates to a school). In this coaching, they were assigned to determine topics to use in teaching practice, establish learning objectives according to the main and basic competencies for a 90-minute teaching practice session, design concept maps and CR, and draw up learning designs (lesson plan, worksheet and assessment).

On days 6 to 8, they participated in the programmes of peer teaching, reflection and revision. This was repeated three times. Each day, three model teachers alternately presented learning designs, about which supervisors encouraged reflection, followed by revision of the designs. The last step was to develop the PPER of the coaching. This can be carried out in college in a collaborative way between STEM teacher candidates and their supervisors [33].

Phase 3: Guided practice

This was carried out in college and in a collaborative way between STEM teacher candidates and their supervisors on days 9 and 10. First step was to establish learning objectives and design materials for a two-hour lesson (90 minutes). Materials in this step were different from those in the previous step. Arends said that designing lesson plans is absolutely essential for teachers' teaching-learning activities [34].

Next, it was necessary to collaborate in making concept maps and CR, as well as drawing up learning designs (lesson plan, worksheet and assessment). Also in this phase, the best model teacher in the previous phase presented learning

designs, followed by reflection and revision of the designs. This was done in college. Then, the teacher candidates undertake teaching in schools. Therefore, the model teachers completed real teaching followed by reflection and revision.

For the last assignment, the PPER of the activities was developed in college, with the support of the supervisors. This helps to develop a more innovative approach to teaching in the classroom [35].

Phase 4: Independent practice

This was a collaboration of STEM teacher candidates with mentor-teachers or supervisors. This included:

1) establishment of objectives;

2) making concept maps and CR;

3) learning design (lesson plan, worksheet and assessment);

4) presentation of learning design by two model teachers;

5) reflection and revision.

The learning design was directly practised and implemented by two model teachers before the reflection and revision. Science, technology, engineering and mathematics teacher candidates then wrote the PPER about their experiences as a narrative. They were able to have further communication with supervisors via WhatsApp and emails. Communication with other teacher candidates and teachers can be established directly in school [36].

Phase 5: Evaluation

Evaluation was carried out by supervisors together with STEM teacher candidates. It was focused on the process and result of their collaboration in planning and implementing learning activities during school internship I and II. If the teacher candidates felt there was something to revise or improve, there would be reconsideration and re-observation. The evaluation also summarised various experiences the teacher candidates had during school internship I and II.

The evaluation was based on the observation results in peer teaching. In addition to making an assessment, the teacher candidates serving as students also make written suggestions [37]. Afterwards, two teacher candidates serving as a moderator and minute-taker led a reflection session. Every one of the teacher candidates had an equal right to express what they felt during the programme, concerning whether the implementation ran as targeted, whether the objectives were accomplished and what obstacles there were.

Such teaching experiences and the result of reflection and evaluation were used to develop the PPER, which contains thoughts about the learning processes. The result of reflection expressed in the PPER can include what aspect of the learning they managed to accomplish, what should not have happened, how the interaction worked, and whether or not the learning experiences of the students varied. Finally, supervisors gave feedback, reinforcement or support.

CONCLUSIONS

The model of LS-CRPPER aimed to enhance STEM teacher candidates in the State University of Malang, Indonesia. This was based on research of the development of lesson study in higher educational institutions. The authors have recently implemented the planning LS-CRPPER model for the course of school internship for STEM teacher candidates in universities.

Five phases of the LS-CRPPER model are preparation, coaching, guided practice, independent practice and programme evaluation. These are systematically implemented in colleges and schools where the STEM teacher candidates take part in a school internship for teachers.

There are five factors to be considered in implementing the LS-CRPPER model, the first of which is the preliminary study used as a basis of preparing a draft of the model of LS-CRPPER. The second is the development of the model based on the initial analysis. This model is a fusion of CR and PPER with LS. Such fusion is called the LS-CRPPER model. Content representation and PPER constitute the PCK representation to be provided to STEM teacher candidates. The third is to provide learning instruments, including syllabus, student worksheets, and assessments. The instruments can be guide books that are validated by experts in a forum through forum group discussion (FGD).

The implementation of the LS-CRPPER model with a limited test in a class is the fourth factor. Six to eight STEM teacher candidates were gathered in a group with a supervisor with the aim of validating the model and its instruments, its practicality and applicability, teacher candidates' activities, possible obstacles, and its effectiveness in enhancing the ability to plan and implement learning practices.

The last factor is the wider implementation of LS-CRPPER. For instance, it could be implemented in two classes. For such an implementation, is important to take into consideration its validity, practicality and effectiveness in comparison with other models. The one-group pre-test-post-test design will be the most appropriate design.

REFERENCES

1. OECD, *Education in Indonesia: Rising to the Challenge*. Paris: OECD Publishing (2015).
2. Blanton, L.P., Sindelar, P.T. and Correa, V.I., Models and measures of beginning teacher quality. *The J. of Spec. Educ.*, 40, **2**, 115-127 (2006).
3. Nilsson, P. and Loughran, J., Exploring the development of pre-service science elementary teachers' pedagogical content knowledge. *J. of Sci. Teac. Educ.*, 23, **7**, 699-721 (2012).
4. Shulman, L., Knowledge and teaching: foundations of the new reform. *Harvard Educ. Rev.*, 57, **1**, 1-23 (1987).
5. van Driel, J.H. and Berry, A.K., *Developing Pre-Service Teachers' Pedagogical Content Knowledge*. In: Clandinin, D. J. and Husu, J. (Eds), The SAGE Handbook of Research on Teacher Education. California: Sage Publications Inc., 561-576 (2017).
6. Etkina, E., Pedagogical content knowledge and preparation of high school physics teachers. *Phys. Rev. ST - Phys. Educ. Res.*, 6, **2**, 1-26 (2010).
7. Williams, J. and Lockley, J., Using CoRes to develop the pedagogical content knowledge (PCK) of early career science and technology teachers. *J. of Tech. Educ.*, 24, **1**, 34-53 (2012).
8. Lee, E. and Luft, J.A., Experienced secondary science teachers' representation of pedagogical content knowledge. *Inter. J. of Sci. Educ.*, 30, **10**, 1343-1363 (2008).
9. Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N. and Ndlovu, T., The place of subject matter knowledge in pedagogical content knowledge: a case study of South African teachers teaching the amount of substance and chemical equilibrium. *Inter. J. of Sci. Educ.*, 30, **10**, 1365-1387 (2008).
10. Seung, E., The process of physics teaching assistants' pedagogical content knowledge development. *Inter. J. of Sci. and Math. Educ.*, 11, **6**, 1303-1326 (2013).
11. Demkanin, P., Preparation of new physics teachers from various perspectives. *J. of Baltic Sci. Educ.*, 12, **1**, 4-5 (2013).
12. Raharjo, S.B., Evaluasi trend kualitas pendidikan di Indonesia. *J. Pen. dan Eval. Pend.*, 16, **2**, 511-532 (2013) (in Indonesian).
13. Tatang, S., Lesson study in Indonesia: an Indonesia University of Education experience. *Inter. J. for Les. and Learn. Stud.*, 1, **3**, 196-215 (2012).
14. Zendrato, J., Tingkat penerapan rencana pelaksanaan pembelajaran dalam pelaksanaan pembelajaran di kelas: Suatu studi kasus di SMA Dian Harapan Jakarta (The level of implementation from learning plan in applying of classroom learning: a case study at SMA Dian Harapan, Jakarta). *Scholaria*, 6, **2**, 58-73 (2016) (in Indonesian).
15. Nsamenang, A.B. and Tchombe, T.M., *Handbook of African Educational Theories and Practices: A Generative Teacher Education Curriculum*. Cameroon: Human Development Resource Centre (HDRC) (2011).
16. Bennie, A., Peralta, L., Gibbons, S., Lubans, D. and Rosenkranz, R., Physical education teachers' perceptions about the effectiveness and acceptability of strategies used to increase relevance and choice for students in physical education classes. *Asia-Pacific J. of Teac. Educ.*, 45, **3**, 302-319 (2017).
17. Purwaningsih, E., Potret representasi pedagogical content knowledge (PCK) guru dalam mengajarkan materi getaran dan gelombang pada siswa SMP (Portrait representation of pedagogical content knowledge (PCK) teachers in teaching the material of vibration and wave at junior high school students). *Indonesian J. of Appl. Phys.*, 5, **1**, 9-15 (2015) (in Indonesian).
18. Silaban, S., Kajian pelaksanaan kurikulum tingkat satuan pendidikan (KTSP) Kimia SMA Negeri di Sumatera Utara (Study of Implementation from the Curriculum of Education Unit Level (CEUL) at Public General High School, Department of Chemistry in North Sumatera) (2011), 09 November 2016, http://digilib.unimed.ac.id/id/eprint/626 (in Indonesian).
19. Bakri, F. and Raharjo, S.B., Analisis hasil uji kompetensi guru fisika (Result analysis of physics teacher competence test). *J. Pen. & Pengem. Pend. Fis.*, 1, **1**, 1-6 (2015) (in Indonesian).
20. Rozenszajn, R. and Yarden, A., Expansion of biology teachers' pedagogical content knowledge (PCK) during a long-term professional development program. *Res. in Sci. Educ.*, 44, **1**, 189-213 (2014).
21. Williams, J., Eames, C., Hume, A. and Lockley, J., Promoting pedagogical content knowledge development for early career secondary teachers in science and technology using content representations. *Res. in Scie. & Tech. Educ.*, 30, **3**, 327-343 (2012).
22. Ní Shúilleabháin, A., Lesson study in a community of practice: a model of in-school professional development. *Trinity Educ. Pap.*, 2, **2**, 22-40 (2013).
23. Hume, A. and Berry, A., Constructing CoRes - a strategy for building PCK in pre-service science teacher education. *Res. in Scie. Educ.*, 41, **3**, 341-355 (2011).
24. Chordnork, B. and Yuenyong, C., Constructing CoRe as a methodological for capturing pedagogical content knowledge: A case study of Thailand teachers teaching global warming. *Proc. - Soc. and Behav. Scie.*, 116, Supplement C, 421-425 (2014).
25. Bertram, A. and Loughran, J., Science teachers' views on CoRes and PaP-eRs as a framework for articulating and developing pedagogical content knowledge. *Res. in Scie. Educ.*, 42, **6**, 1027-1047 (2012).

26. Jang, S.J., *Developing a Peer-Coaching Model for Enhancing the Pedagogical Content Knowledge of Preservice Science Teachers*. In: Tan, K.C.D. and Kim, M. (Eds), Issues and Challenges in Science Education Research: Moving Forward. Dordrecht: Springer Netherlands, 107-123 (2012).
27. Pusca, D. and Northwood, D.O., The *why*, *what* and *how* of teaching: an engineering design perspective. *Global J. of Engng. Educ.*, 19, **2**, 106-111 (2017).
28. Sarker, P.K., Use of concept maps for problem-solving in engineering. *Global J. of Engng. Educ.*, 17, **1**, 29-33 (2015).
29. Magnusson, S., Krajcik, J. and Borko, H., *Nature, Sources, and Development of Pedagogical Content Knowledge for Science Teaching*. In: Gess-Newsome, J. and Lederman, N.G. (Eds), Examining Pedagogical Content Knowledge: the Construct and its Implications for Science Education. Dordrecht: Springer Netherlands, 95-132 (1999).
30. Juhler, M.V., The use of lesson study combined with content representation in the planning of physics lessons during field practice to develop pedagogical content knowledge. *J. of Scie. Teac. Educ.*, 27, **5**, 533-553 (2016).
31. Council, N.R., *Classroom Assessment and the National Science Education Standards*. Washington, DC: The National Academies Press (2001).
32. Mnguni, L.E., The theoretical cognitive process of visualization for science education. *SpringerPlus*, 3, **184**, 1-9 (2014).
33. McCarthy, D.S. and Burns, B.A., *Mathematics Teacher Education and edTPA: Complex Assessing*. In: Management Association (Ed), K-12 STEM Education: Breakthroughs in Research and Practice. USA: IGI Global, 149-168 (2017).
34. Arends, R.I., *Learning to Teach.* (10th Edn), New York: McGraw-Hill Education (2015).
35. Martin-Gamez, C., Prieto-Ruz, T. and Jimenez-Lopez, M.A., Developing preservice science teachers' beliefs about new approaches to science education. *J. of Turkish Scie. Educ.*, 13, **4**, 213-236 (2016).
36. Anwar, A.H.M.F., Blending students' feedback in flexible teaching-learning. *Global J. of Engng. Educ.*, 15, **1**, 28-34 (2013).
37. Fernandez, C.E. and Yu, J., Peer Review of Teaching. *The J. of Chiropractic Educ*., 21, **2**, 154-161 (2007).

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