# Physics Teachers' Pedagogical Content Knowledge (PCK) in Developing Content Representation (CoRe) on the Topic of Classical Mechanics

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**Abstract.** This study aims to describe physics teachers' ability to represent their content knowledge and pedagogy on classical mechanics concept using a CoRe framework in teaching practice, and to figure out their ability to develop the CoRe according to the length of teaching experiences, educational levels, and gender. The data were collected by reviewing the CoRe documents created by 40 high school physics teachers in Central Java and the Yogyakarta Special Region as a part of in-service training activities. The RASCH model was employed to analyze the research data, both qualitatively and quantitatively. The results of the study revealed that teachers were able to develop the CoRe with high qualification (76,1%). There was no teacher with poor and even fail categories. The ability to develop the CoRe will support them in designing a classroom learning. The aspect that requires improvement is the statement about outlining the material structures that will be delivered to students based on their mastery levels. The findings employing the DIF analysis showed that the length of teaching experiences had an effect on differences in the ability to develop the CoRe on the aspects of big idea development, material choices and sequences of delivery. Nevertheless, the ability of male and female teachers to develop CoRe is relatively similar. Meanwhile, physics teachers with master degree have better identification skills and procedures for the significance of big idea development than those with bachelor degree do.

**Key words:** pedagogical content knowledge; content representation; classical mechanics; in-service training.

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## INTRODUCTION

A teacher's Pedagogical Content Knowledge (PCK) is the main key to the success of classroom learning activities [1]. Teachers with PCK mastery will be able to fully understand how students construct knowledge, acquire skills, and develop positive learning habits [2,3]. It has also been revealed in science learning that there is a direct relationship between the teachers' PCK ability and the practice of classroom learning implementation [4]. However, they do not always recognize the importance of PCK, as indicated by a lack of subject-matter understanding and separate knowledge [5]. PCK serves as a component that represents a teacher's professional skill [6]. PCK is also a thinking concept that provides an understanding that in teaching science, it does not only deal with understanding the content of science materials (knowing science), but also with the teaching methods (how to teach) [7].

The science teachers' PCK is often tacit and difficult to represent since it is a truly personal construct [5]. Content Representation (CoRe) and Pedagogical and Professional-experience Repertoires (PaP-eRs) are documents that effectively articulate the framework and depict the aspects of tacit, intrinsic, and professional teacher knowledge which is then known as Pedagogical Content Knowledge (PCK). CoRe is a table that is designed to represent the science teachers' understanding of a specific topic content [8]. This is accomplished by requiring them to consider a big idea of the topic being taught. The line includes eight main questions designed to reveal the teacher's motivations for pedagogical choices/activities, student knowledge such as alternative conceptions, and difficulties such as how to assess student understanding [8].

However, many science teachers lack a deep conceptual understanding of science, their ideas on specific science topics are fragmented and poorly structured [9]. They require assistance and guidelines in developing PCK in order to carry out their profession as qualified teachers in the learning process ([10,11]. One of the ways to help teachers improve their competences is through in-service training program. This program, which is in the form of training, is essential in improving teachers' professionalism and it has a positive impact on subject matter knowledge, classroom management, teaching methods, and student evaluation [12]. The Covid-19 pandemic has changed conventional learning activities from face-to-face to online learning in order to avoid physical contact [13,14]. This also has an impact on the training program which was previously conducted classically, shifted to online training.

According to the findings of preliminary interviews towards physics teachers, the obstacles encountered include teachers' difficulty in analyzing basic competences and competence achievement indicators in physics, narrow scopes of the selected materials, use of appropriate teaching media, and incidental misconceptions in learning activities. The challenges that these teachers face are related to their experiences, pedagogical capacities, and content mastery. There are no data or information available that report on the physics teachers' PCK profiles, particularly those that relate to aspects such as length of teaching experience, gender, and educational level.

This study aims to describe physics teachers' ability to represent their content knowledge and pedagogy according to the CoRe framework of classical mechanics concept in teaching practice, and to figure out their ability to develop the CoRe according to their length of teaching experience, educational level, and gender aspects.

## METHOD

This study employed both qualitative and quantitative approaches. The respondents in this study were 40 high school physics teachers who took part in an online training for high school physics teachers in Central Java and Yogyakarta, and who fit the demographic profiles shown in Table 1.

**Tabel 1**. Physics teachers' demographic profiles

| Aspects of Demography | | Respondents | Percentage |
|---|---|---|---|
| Gender | Male | 5 | 12.5 |
| | Female | 35 | 87.5 |
| Educational level | Bachelor degree | 36 | 90 |
| | Master degree | 4 | 10 |
| Teaching experience | 1 to 6 years | 12 | 30 |
| | 7 to 12 years | 11 | 27.5 |
| | 13 to 18 years | 14 | 35 |
| | 19 to 24 years | 1 | 2.5 |
| | 25 to 30 years | 2 | 5 |

The CoRe instrument developed by Loughran John was employed in this study [5]. This instrument can be used to assess teachers' PCK ability. The data were in the form of documents compiled by the CoRe which were analyzed on each 'big idea' of the classical mechanics concept. The CoRe instrument comprises of eight main questions, which are outlined as follows;

1. What will you teach to your students about the idea/concept?
2. Why is it important for students to understand the concept?
3. What ideas about the concept do students not yet have?
4. Are there any difficulties in teaching the concept?
5. What are the most common errors (misconceptions) in teaching the concept?
6. What factors influence your teaching style?
7. What are the teaching procedures for teaching the concept?
8. How do you determine whether students understand or are confused by the concept?

There are three additional aspects assessed in this study, including subject identity, big idea, and neatness. As a result, there are 11 aspects in totals used in this study. Each aspect was also measured using a Likert scale rubric ranging from 1 (very poor) to 5 (very good). Furthermore, the results of the physics teacher's CoRe ability analysis were compared with the criteria for the teachers' ability to develop the CoRe [15], as shown in Table 2.

**Table 2.** Criteria of the teachers' ability to develop CoRe

| Score interval | Criteria |
|---|---|
| 85 -100 | Very good |
| 70 – 84.9 | Good |
| 55 – 69.9 | Sufficient |
| 30 – 54.9 | Poor |
| <30 | Fail |

As shown in Appendix 1, the measurement instrument has a special unidimensionality (62.9%), indicating that the raw variance is above the standard 40%. [16]. This exemplifies that the instrument used can measure what is supposed to measure. The rating scale analysis reveals that the rating scale ranging from very bad to very good is easy to understand, with an average value ranging from -2.01 to 5.09.

According to Table 3, the person reliability index value (0.80) indicates that the consistency of the person's responses to the items is sufficient [17]. Similarly, the item reliability measure (0.96) has a special classification. High item reliability indicates that the item accurately defines the latent variable [18]. In other words, the instrument for assessing the reliable teacher's CoRe documents were employed for different groups of respondents. The Cronbach Alpha coefficient value (0.76) indicates that the interaction between the items and the person is 'good'.

**Table 3.** Person and item Reliability

| | Mean Logit | Reliability | Alpha Cronbach |
|---|---|---|---|
| Person | 1.70 | 0.80 | 0.76 |
| Item | 0.00 | 0.96 | |

The RASCH measurement model with WINSTEPS version 3.75 software was used to determine the instrument's validity and reliability. Through the calibration of person and item reliability, WINSTEPS software mathematically transformed raw ordinal data (Likert-type data) based on frequency of response which appears as probability to become logit (log odd unit) via the logarithm function, which assesses the overall fit of the instrument as well as person fit [18,19]. Furthermore, Differential Item Functioning (DIF) was used to identify the results of measuring aspects of the CoRe documents based on the demographic profiles such as gender, teaching experience, and educational level. DIF provides information on the different types of the teacher trainees based on the demographic characteristics.

## RESULTS AND DISCUSSION

### Physics teachers' ability in developing the CoRe

The physics teachers' ability in developing the CoRe as a tool for designing physics learning based on each individual's level of achievement. Based on the data analysis results, the average percentage score for the CoRe development is 76,1% (3,81). The percentage of the physics teacher's ability in developing the CoRe is shown in Table 4.

**Table 4.** The percentage of the achievement level of physics teachers' ability in developing the CoRe

| Category | Frequency | Percentage |
|---|---|---|
| Very good | 4 | 10 |
| Good | 27 | 67.5 |
| Sufficient | 9 | 22.5 |
| Poor | 0 | 0 |
| Fail | 0 | 0 |

Table 4 shows that physics teachers are capable of developing the CoRe. The total percentage of the very good and good categories is 77,5% (31 teachers). In other words, more than the minimum level of criteria (75%) belongs to good category. The percentage of concept categories selected in the development of classical mechanics CoRe is under the straight motion topic category. 25% of teachers selected to develop the CoRe concept. Meanwhile, the least selected category is under the linear motion topic category, selected by one teacher only (2,5%).

**Table 5.** The concept categories on the developed CoRe.

| Category | Frequency | Percentage |
|---|---|---|
| Linier Motion | 10 | 25 |
| Newton's Law | 7 | 17.5 |
| Momentum and Impulse | 4 | 10 |
| Parabolic Motion | 5 | 12.5 |
| Work and Energy | 6 | 15 |
| Simple Harmonic Motion | 2 | 5 |
| Circular Motion | 2 | 5 |
| Vector | 3 | 7.5 |
| Rigid Object | 1 | 2.5 |

According to the average scores of the teacher's ability to develop the CoRe in Appendix 2, the statement item about what concepts are not yet known by high school students have the lowest score of 2,35. That is, the teachers find it difficult to outline the material structures that will be delivered to students based on their levels of mastery. It is very importance for a teacher to be able to structure the learning materials in the classroom. There are three strategies to make sure that PCK runs smoothly, such as through planning, teaching, and reflecting [21]. Mastery of Content Knowledge (CK) has a positive contribution to the teachers' PCK ability [22]. Meanwhile, a statement about the sequence/flow selected to teach the concept of each big idea has the highest average score (4,15). This indicates that the majority of physics teachers are already aware of the pedagogical aspect or how to teach the content in the classroom learning activities. The teacher's pedagogical knowledge helps in the selection of learning strategies and representational abilities [23].

### Differences between the teacher demography and the developed CoRe

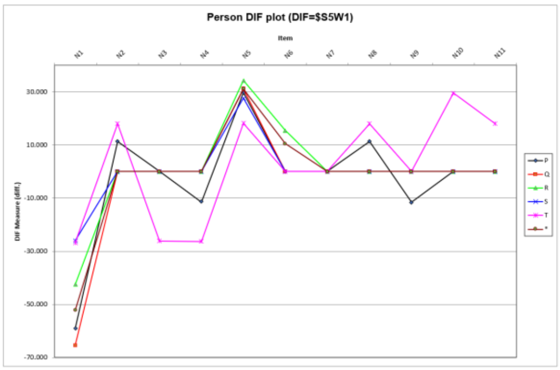


**Figure 1.** Person DIF Plot based on the length of teaching experience.

Note: P (1 to 6 years); Q (7 to 12 years); R (13 to 18 years); S (19 to. 24 years); T (25 to 30 years).

According to Figure 1, there are 11 items based on the length of teaching experience N1 (complete identity and the CoRe title). It can be seen that the Q coded-teacher (with 7-12 years of teaching experience) is more complete in writing the CoRe subject identity than the other groups of teachers. Item N2 (*big idea* appearing on the CoRe) shows that teachers with 25 to 30 years of teaching experienced raise fewer big ideas than teachers with 1 to 6 years of experience. Item N3 (*a statement about what I intended the students to learn about the idea*) shows that teachers with 25 to 30 years of experience have higher quality in what will be taught based on the big ideas than other groups of teachers. On item N4 (*A statement about why is it important for the students to know this*) and N5 (*a statement about what else do you know about this idea (that you do not intend the students to know yet*), the teachers with 25 to 30 years of experience have compelling reasons for the importance of students understanding the concepts (big ideas) and ones which have not yet been taught to students. On item N6 (*A statement on knowledge about students' thinking that influences your teaching of this idea*), teachers with 13 to 18 years of experience did not find a complex description of difficulties, compared to other groups of teachers. Item N7 (*A statement about knowledge about students' thinking that influences your teaching of this idea*) shows that all groups of teachers provide relatively the same description. In item N8 (*A statement about other factors influencing your teaching of this idea*), N9 (*A statement about teaching procedures and specific reasons for using these to engage with this idea*), and N10 (*A statement about specific ways of determining students' understanding or confusion around this idea (includes likely range of responses*), it appears that teachers with 13 to 18 years of experience have a better description of student conditions, teaching considerations, and strategies in determining student understanding than other groups of teachers. Item N11 (*neatness*) states that the CoRe compiled by the group of teachers is structured and neat, except those with 13 to 18 years of experience. According to the description, teachers with more experience will be able to develop the CoRe better, particularly in terms of developing big ideas, selecting and delivering materials according to its order, and so on. The length of a teacher's teaching experience becomes one of the aspects in determining the extent to which a teacher develops the best strategy in planning the learning process [23,24].

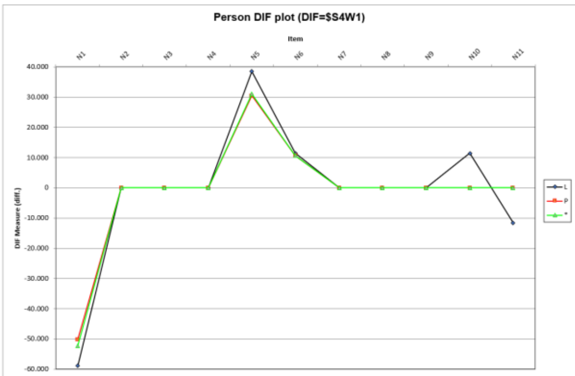


**Figure 2.** Person DIF Plot based on gender.

Note : L = Male, P = Female

According to Figure 2, the result of item N1 shows that male teachers are more complete than female teachers in writing their identities in the CoRe header. Whereas, item N2, N3, N4, N6, N7, N8, and N9 relatively show the similar results between male and female teachers. Item N5 (*a statement about what else you know about this idea (that you do not intend the students to know yet*) and N10 indicate that female teachers are more detailed than male teachers in describing what concepts students do not know yet and how to know students' understanding compared to male teachers. Item N10 (*A statement about specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses*) shows that in terms of neatness, the male group's CoRe structure is neater than the female group's. Gender equality plays an important role in the practice of science learning in the classroom [25, 26]. In this study, it can be seen that the CoRe's main statement between male and female teachers has relatively similar ability in developing the CoRe.


**Figure 3.** Person DIF plot based on education level

Note: A = Bachelor Degree, B = Master Degree

According to Figure 3, on item N1 (subject identity), N4 (A statement about why is it important for the students to know this) and N9 (A statement about teaching procedures and particular reasons for using these to engage with this idea), teachers with master degree level provide a better description of CoRe than those with bachelor degree level do. On item N6 (A statement about the difficulties/limitations of teaching the Ideas), teachers with bachelor degree level provide a better description than those with master degree level. The other items, on the other hand, show relatively similar results between both teachers with bachelor degree and those with master degree levels [28]. This is in line with studies on TPACK teachers from 5 Asian and European countries that examines the contribution of education level and gender.

## CONCLUSION

Teachers can develop the CoRe with good qualification (76,1%). There is no physics teacher who has been labelled as poor or fail in developing the CoRe. The ability to develop the CoRe will support them in designing a classroom learning. The aspect that requires improvement is a statement about outlining the learning material structures that will be delivered to students based on their levels of mastery. The findings of the DIF analysis show that the length of teaching experience has an effect on differences in the ability in developing the CoRe in terms of big idea development, material choices and sequences of delivery. Yet, both male and female teachers' ability is relatively similar. Meanwhile, in terms of educational level, physics teachers with master degree have better identification skills and procedures for the importance of big ideas than those with bachelor degree do.

## REFERENCES

L. Shulman, Knowledge and Teaching:Foundations of the New Reform, Harv. Educ. Rev. 57 (1987) 1–23. https://doi.org/10.17763/haer.57.1.j463w79r56455411.

P. Mishra, M.J. Koehler, Technological pedagogical content knowledge: A framework for teacher knowledge, Teach. Coll. Rec. 108 (2006) 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x.

P. Brown, P. Friedrichsen, S. Abell, The Development of Prospective Secondary Biology Teachers PCK, J. Sci. Teacher Educ. 24 (2013) 133–155. https://doi.org/10.1007/s10972-012-9312-1.

H. Retnawati, Hambatan Guru Matematika Sekolah Menengah Pertama Dalam Menerapkan Kurikulum Baru, J. Cakrawala Pendidik. 3 (2016). https://doi.org/10.21831/cp.v3i3.7694.

J. Loughran, A. Berry, P. Mulhall, eds., Understanding and Developing Science Teachers' Pedagogical Content Knowledge, SensePublishers, Rotterdam, 2012. https://doi.org/10.1007/978-94-6091-821-6.

M. Evens, J. Elen, F. Depaepe, Developing Pedagogical Content Knowledge: Lessons Learned from Intervention Studies, Educ. Res. Int. 2015 (2015) 1–23. https://doi.org/10.1155/2015/790417.

Sri Sukaesih; Saiful Ridlo; Sigit Saptono, Profil Kemampuan Pedagogical Content Knowledge (PCK) Calon Guru Biologi, Lembaran Ilmu Pendidik. 46 (2017) 68–74. https://doi.org/10.15294/lik.v46i2.11026.

A. Bertram, 'CoRes and PaP-eRs as a strategy for helping beginning primary teachers develop their pedagogical content knowledge, Educ. Química. 25 (2014) 292–303. https://doi.org/10.1016/S0187-893X(14)70545-2.

J. Loughran, P. Mulhall, A. Berry, Exploring Pedagogical Content Knowledge in Science Teacher Education, Int. J. Sci. Educ. 30 (2008) 1301–1320. https://doi.org/10.1080/09500690802187009.

P. Nilsson, When Teaching Makes a Difference: Developing science teachers' pedagogical content knowledge through learning study, Int. J. Sci. Educ. 36 (2014) 1794–1814. https://doi.org/10.1080/09500693.2013.879621.

R. Rozenszajn, A. Yarden, Expansion of Biology Teachers' Pedagogical Content Knowledge (PCK) During a Long-Term Professional Development Program, Res. Sci. Educ. 44 (2014) 189–213. https://doi.org/10.1007/s11165-013-9378-6.

C.M.Z.C. Omar, Need for In-Service Training for Teachers and It's Effectiveness In School., Int. J. Innov. Educ. Res. 2 (2014) 1–9. https://doi.org/10.31686/ijier.vol2.iss11.261.

C. Carrillo, M.A. Flores, COVID-19 and teacher education: a literature review of online teaching and learning practices, Eur. J. Teach. Educ. 43 (2020) 466–487. https://doi.org/10.1080/02619768.2020.1821184.

A. Juanda, A.S. Shidiq, D. Nasrudin, Teacher Learning Management: Investigating Biology Teachersâ€™ TPACK to Conduct Learning During the Covid-19 Outbreak, J. Pendidik. IPA Indones. 10 (2021) 48–59. https://doi.org/10.15294/jpii.v10i1.26499.

S. Suripah, S. Suyata, H. Retnawati, Pedagogical Content Knowledge (PCK) Mathematics Pre-service Teachers in Developing Content Representations (CoRes), Int. J. Emerg. Math. Educ. 5 (2021) 41. https://doi.org/10.12928/ijeme.v5i1.19954.

W. Fisher, Rating Scale Instrument Quality Criteria, Rasch Meas. Trans. 21 (2007) 1095.

W. Sumintono, B., & Widhiarso, Application of rasch modelling in social science research, revised edition, Trimkom Publishing House, Cimahi, 2014.

C.. Bond, T.G., & Fox, Applying the Rasch Model, Fundamentals Measurement in the Human Sciences, 3rd ed., Routledge, New York, 2015.

J.M. Linacre, Many-Facet Rasch Measurement: Facets Tutorial, (2012). http://winsteps.com/tutorials.htm.

T.G. Bond, C.M. Fox, Applying the Rasch Model, Psychology Press, 2013. https://doi.org/10.4324/9781410614575.

A.C. Alonzo, A. Berry, P. Nilsson, Unpacking the Complexity of Science Teachers' PCK in Action: Enacted and Personal PCK, in: Repositioning Pedagog. Content Knowl. Teach. Knowl. Teach. Sci., Springer Singapore, Singapore, 2019: pp. 273–288. https://doi.org/10.1007/978-981-13-5898-2_12.

C. Kulgemeyer, J. Riese, From professional knowledge to professional performance: The impact of CK and PCK on teaching quality in explaining situations, J. Res. Sci. Teach. 55 (2018) 1393–1418. https://doi.org/10.1002/tea.21457.

S. Park, J. Suh, K. Seo, Development and Validation of Measures of Secondary Science Teachers' PCK for Teaching Photosynthesis, Res. Sci. Educ. 48 (2018) 549–573. https://doi.org/10.1007/s11165-016-9578-y.

M.E. Sheppard, R. Wieman, What do teachers need? Math and special education teacher educators' perceptions of essential teacher knowledge and experience, J. Math. Behav. 59 (2020) 100798. https://doi.org/10.1016/j.jmathb.2020.100798.

T. Pressley, H. Croyle, M. Edgar, Different approaches to classroom environments based on teacher experience and effectiveness, Psychol. Sch. 57 (2020) 606–626. https://doi.org/10.1002/pits.22341.

C. Chikunda, P. Chikunda, Patriarchy Rules: Transforming resistance to gender inequalities in science teacher education in Zimbabwe, Cult. Pedagog. Inq. 8 (2016). https://doi.org/10.18733/C3JG64.

D. Sansone, Why does teacher gender matter?, Econ. Educ. Rev. 61 (2017) 9–18. https://doi.org/10.1016/j.econedurev.2017.09.004.

J. Castéra, C.C. Marre, M.C.K. Yok, K. Sherab, M.A. Impedovo, T. Sarapuu, A.D. Pedregosa, S.K. Malik, H. Armand, Self-reported TPACK of teacher educators across six countries in Asia and Europe, Educ. Inf. Technol. 25 (2020) 3003–3019. https://doi.org/10.1007/s10639-020-10106-6.