

DEVELOPING HIGH SCHOOL MATHEMATICS LEARNING MODELS BASED ON “PEDAGOGICAL CONTENT KNOWLEDGE” OF PROFESSIONAL MATHEMATICS TEACHERS

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Abstract

Pedagogical content knowledge is teachers' knowledge and experience in teaching specific content. However, professional mathematics teachers have not used it as a basis for information in developing mathematics learning models. This study aims to produce a mathematics learning model based on the knowledge and experience of professional teachers in teaching sequences and series. This study uses a development model with the Plomp scheme, which consists of 5 stages: initial investigation, design, realization/construction, testing, and implementation. The subjects in this study were eight high school teachers who have experience and excellent reputations. Data collection techniques are documentation, FGD, observation, questionnaires, and tests. The data analysis in this study was qualitative, using percentage-based techniques and vignette analysis of learning outcomes. The results showed that after the needs analysis, realization, and design stages, the product was tested through expert reviews and assessments. The assessment results showed that the product was valid and practical. The implementation stage was conducted in 3 schools, with 147 students as research participants. The results showed that the developed model had a positive, potential impact, as students were more constructive in their learning. Thus, the developed model can serve as a reference for mathematics learning, particularly for sequences and series. During the learning process, students are more creative and constructive, and follow the concept of in-depth learning in a pedagogical context.

Keywords: Learning model; pedagogical content knowledge; professional teachers

Abstrak

Pedagogical content knowledge merupakan pengetahuan dan pengalaman guru dalam mengajarkan materi tertentu, namun demikian, guru matematika profesional belum digunakan sebagai dasar informasi dalam mengembangkan model pembelajaran matematika. Penelitian ini bertujuan untuk menghasilkan model pembelajaran matematika berbasis pada pengetahuan dan pengalaman guru profesional dalam mengajarkan materi barisan dan deret. Penelitian ini menggunakan model pengembangan dengan skema Plomp, yang terdiri dari 5 tahap, yaitu investigasi awal, desain, realisasi/konstruksi, pengujian, dan implementasi. Subjek dalam penelitian ini adalah delapan guru SMA yang telah memiliki pengalaman dan reputasi yang sangat baik. Teknik pengumpulan data adalah dokumentasi, FGD, observasi, kuesioner dan tes. Analisis data yang digunakan dalam penelitian ini adalah analisis kualitatif dengan menggunakan teknik persentase dan analisis vignette hasil belajar. Hasil penelitian menunjukkan bahwa setelah tahap analisis kebutuhan, realisasi, dan desain, produk diuji dengan melakukan telaah dan penilaian oleh para ahli dan praktisi profesional. Hasil penilaian menunjukkan bahwa produk valid dan praktis. Tahap implementasi dilakukan di 3 sekolah dengan 147 siswa sebagai objek penelitian. Hasil penelitian menunjukkan bahwa model yang dikembangkan memiliki dampak positif dan potensial karena siswa lebih konstruktif dalam pembelajaran. Dengan demikian, model yang dikembangkan dapat digunakan sebagai acuan dalam pembelajaran matematika, khususnya mengenai materi barisan dan deret. Selama proses pembelajaran siswa lebih kreatif dan konstruktif, serta mengikuti konsep pembelajaran mendalam dalam konteks pedagogis.

Kata kunci: Model pembelajaran; pedagogical content knowledge; guru profesional



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INTRODUCTION

Teachers are the most influential actors in shaping students' learning experiences because they translate national education policies into practical actions in schools (Unicef, 2007). Teachers as learning agents and change agents play roles as facilitators, motivators, instructional designers, and inspirational figures for students (Kultsum, 2017; Astuti et al., 2021; Purwoko, Kusumaningrum, et al., 2023; Purwoko RY, Pratiwi HD, 2022).

Teachers must be able to design instructional plans and manage constructive classes so students can learn properly and finally achieve intellectual maturity as the goal of education and as a professional force determining the destiny of the nation. Then, research conducted by the OECD confirms that teacher quality is the most dominant factor in determining students' success. Therefore, having a qualified and professional teaching workforce is one way to improve the quality of education (Kemendikbud-ristek, 2023; Mahfud et al., 2019; PISA, 2016; Sudiyatno et al., 2019).

Based on Constitution No. 14 of 2005, a teacher is required to master four competencies such as: pedagogical, professional, social, and personality competences (UU No 14 Tahun 2005). It was introduced by Lee Shulman in 1986. According to Shulman, PCK is a combination of two types of competencies; pedagogical and content knowledge.

In mathematics education, integrating these two competencies is particularly crucial because mathematical concepts are abstract and require appropriate pedagogical transformations for students to understand them meaningfully, as shown in Figure 1.

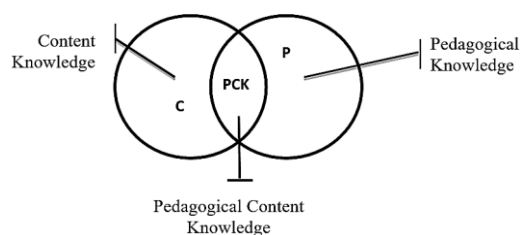


Figure 1. PCK Lee Shulman

PCK is very essential for a teacher to increase teaching competence and the effectiveness of learning processes (Depaepe et al., 2013; Kultsum, 2017; Purwoko et al., 2019; Van Driel & Berry, 2012).

Recent studies over the last decade have examined PCK in mathematics education from various perspectives, including its role in instructional design, teacher professional development, and student achievement; however, most of these studies have focused on measuring or analyzing PCK rather than on developing instructional models grounded in teachers' professional PCK.

It must be supported by some previous studies on the development of instructions and the research of PCK in learning mathematics. A research on PCK model development was conducted by John K. Lannin which states that learning mathematics in the classroom can be successful if there are components of knowledge and experience of mathematics teachers such as: 1) Knowledge of Instructional Strategies for Mathematics, 2) Knowledge of Students' Understanding within Mathematics, 3) Knowledge of Curriculum for Mathematics, and 4) Knowledge of Assessment for Mathematics which can be integrated into mathematics learning (Lannin et al., 2013). The components of PCK model in mathematics learning was figured in Figure 2.

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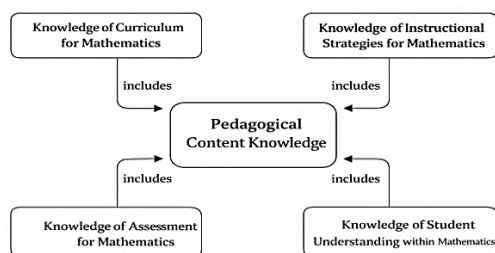


Figure 2. PCK model in mathematics learning

Based on Figure 2, it is explained that the mathematics teacher's knowledge must bring four main knowledge namely: 1) curriculum knowledge focusing on how to deal with the aim of learning-teaching process, 2) teachers' knowledge on how to use some appropriate learning strategies according to the material, 3) teachers' knowledge on how to understand mathematics learning and 4) teachers' knowledge on how to conduct assessments in learning mathematics.

Although the PCK model has been conceptually outlined, there are still gaps in translating this framework into a structured high school mathematics learning model that explicitly draws on the knowledge and experience of professional teachers.

Teachers have responsibilities to educate, teach and guide students with a specific mathematical knowledge base. They must be able to design learning instructions and manage the classrooms so they become constructive and transferable (Setiana et al., 2021; Setiana & Purwoko, 2020). The development expected is in the form of the development of learning tools to support student learning activities in the classroom (Purwoko, 2017).

In senior high school mathematics, sequences and series are essential yet cognitively demanding topics. The concepts require students to understand patterns, generalization, recursive and

explicit formulations, and algebraic reasoning (Maryani & Chotimah, 2021). However, classroom practices often emphasize procedural computation over conceptual understanding, resulting in students' difficulty connecting formulas to underlying mathematical structures. This indicates that teachers' Pedagogical Content Knowledge in teaching sequences and series has not been optimally structured into coherent instructional designs. Therefore, the need to develop a PCK-based mathematics learning model specifically for sequences and series is a fundamental rationale for this research.

Therefore, this study aims to develop a high school mathematics learning model based on the Pedagogical Content Knowledge of professional mathematics teachers, a novelty compared with previous studies that have mainly focused on the analysis or measurement of PCK. This study is expected to be useful to improve the quality of mathematics learning to be better in the future.

METHODS

This study described the experience and knowledge of professional teachers as the main base to improve mathematics learning. This knowledge aimed to design mathematical learning instructions that were suitable for senior high school students.

This research developed a product in the form of the learning instruction based on the ability of professional mathematics teachers. The development model used in this study was the Plomp model. The model was implemented to design an initial product in the form of a learning instruction along with a prerequisite test of a good learning instruction. Developing learning (Plomp, 2013) shows a model that consists of five steps, as shown in the Figure 3.

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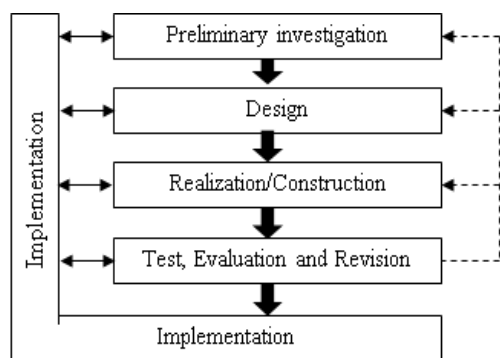


Figure 3. Plomp model development flow

Based on Figure 3, operationally, it is carried out as follows: this study followed the five phases of the Plomp development model: (1) preliminary investigation, (2) design, (3) realization/construction, (4) test, evaluation, and revision, and (5) implementation. In the preliminary investigation phase, the researchers conducted documentation analysis and Focus Group Discussions (FGD) with professional teachers to identify problems in teaching sequences and series and to explore teachers' Pedagogical Content Knowledge (PCK). In the design phase, the initial framework of the learning instruction was formulated based on the identified PCK components. In the realization phase, the prototype of learning tools (lesson plans, teaching materials, and assessment instruments) was developed. During the test, evaluation, and revision phase, expert validation and limited trials were conducted to refine the prototype. Finally, during the implementation phase, the revised product was tested in real classrooms to assess its practicality and effectiveness.

The subjects of the study were 8 professional high school mathematics teachers who had a national reputation in Indonesia. They were used as the key to obtain information about PCK's experience and the abilities to improve mathematics learning instructions.

Then, the three experts did the validation of mathematics learning and also did the revision. The operational test involved three model teachers and 147 students.

The researchers used documentation, FGD, observation, questionnaires, and tests for data collection techniques and the data analysis. They were used to obtain initial and final data information in the study. They were carried out in FGD including the teachers' knowledge and beliefs regarding the aspects of pedagogy, student characteristics, subject matter and curriculum in mathematics learning. The observation aimed to obtain data on the implementation of learning models using learning tools that had been developed in the classroom. The questionnaires were done using the form of validation to obtain data for initial prototype validity before the class. The validity includes face and logical validity. Then, a final test to measure the completeness of student learning towards the learning materials was conducted.

The data of FGD result were analyzed by using a qualitative method namely reduction technique. Then the researchers tried to find out the level of validity, practicality, and effectiveness of the developed learning instructions. It was conducted by following the steps to provide quality criteria for the final product. The form of expert, teacher, and student response scores were obtained through questionnaires. Then they were converted into interval data and the scores to a five scale qualitative data.

To assess the effectiveness of the developed instructional approach, students' post-test scores were analyzed descriptively and compared with the predetermined minimum mastery

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criterion (MMC). The product was considered effective if at least 75% of students scored at or above the MMC. In addition, the mean score of students' learning outcomes was calculated to determine overall achievement levels.

Effectiveness was also supported by positive student responses from questionnaires, indicating that the instructional approach facilitated conceptual understanding of sequences and series.

Table 1. Converting quantitative data to qualitative

Score	Formula	Category
A	$X > \bar{X}_i + 1,80SB_i$	very good/ highly valid
B	$\bar{X}_i + 0,60\bar{X}_i < X \leq \bar{X}_i + 1,80SB_i$	good/ valid
C	$\bar{X}_i - 0,60SB_i < X \leq \bar{X}_i + 0,60SB_i$	fair/ less valid
D	$\bar{X}_i - 1,80SB_i < X \leq \bar{X}_i - 0,60SB_i$	poor / invalid
E	$X \leq \bar{X}_i - 1,80SB_i$	very poor/ invalid

Information:

\bar{X}_i = Average ideal score = $\frac{1}{2}$ (ideal maximum score + ideal minimum score).

SB_i = Ideal standard deviation = $\frac{1}{6}$ (ideal maximum score - ideal minimum score).

X = Actual Score.

RESULTS AND DISCUSSION

Results

Preliminary Investigation Results

The preliminary investigation was conducted through documentation analysis and Focus Group Discussions (FGD) with eight professional mathematics teachers using the Pedagogical Content Knowledge (PCK) framework developed (Lannin et al., 2013). The findings indicate that professional teachers consistently integrate four major PCK components curriculum knowledge, instructional strategies, knowledge of student understanding, and assessment knowledge when teaching sequences and series.

The FGD results show that teachers begin instruction with critical reflection to identify students' misconceptions, particularly regarding patterns, general terms, and the application of formulas in arithmetic and geometric sequences. This reflection phase helps align students' prior knowledge with the new concepts

to be constructed. Teachers also emphasize contextual problems and open-ended questions to stimulate conceptual understanding rather than procedural memorization.

These findings confirm that teachers' experiential PCK served as the foundation for designing the instructional learning developed in this study.

Product Development and Validation

Based on the preliminary findings, a PCK-based mathematics learning model was developed, consisting of lesson plans, modules, student worksheets, and learning achievement tests. The learning design integrated guided discovery, contextual worksheets, open-ended problem-solving, and authentic assessment aligned with Curriculum.

Expert validation was conducted by five validators to determine the feasibility of the developed product. The validation results are presented in Table 2.

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Table 2. Learning instruction validation

No	Learning Instruction	Validator			Average	Category
		1	2	3		
1	Lesson plan	31	32	31	31	Valid
2	Module	47	48	46	47	Valid
3	Student worksheet	95	97	98	97	Valid
4	Learning achievement test	47	48	46	47	Valid

The results indicate that all components of the developed learning instruction are categorized as valid. This means the product fulfills content and construct validity requirements and is appropriate for field testing.

Field Testing Results

Practicality was measured using classroom observation sheets during four meetings involving three model teachers. The observation assessed three aspects: syntax, social system, and principle of reaction. The results are shown in Table 3.

Table 3. Implementation of learning instruction

No	Rated aspect	Observer average score							
		I		II		III		IV	
		1	2	1	2	1	2	1	2
1	Syntax	28	30	31	31	36	37	38	37
2	Social system	29	28	30	32	35	40	37	36
3	Principle of Reaction	14	14	14	17	19	18	19	18
Total score		71	72	75	80	90	95	94	91
Average		84							
Category		Good							

The observation results show an overall average score of 84 in the good category. This indicates that the learning model was implemented consistently according to the designed procedures. Teachers successfully conducted reflection activities, facilitated guided discovery, used contextual worksheets, and implemented open-ended questioning as planned. Therefore, the PCK-based mathematics learning instruction meets the practicality criteria.

Effectiveness Results

The effectiveness of the developed learning instruction was measured using a validated learning achievement test administered after the imple-

mentation of the model. The results are shown in Table 4.

Table 4. Final test results

No	Score obtained	Number of Students	Percentage
1	smaller than 60	31 people	18%
2	greater than 60	142 people	82%

Based on Table 4, 82% of students scored above 60. Because mastery of the classical material exceeded the minimum 75% criterion, the instruction was deemed effective.

Student work samples demonstrate their ability to explain their reasoning, apply various solution stra-

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tegies, and elaborate on their answers when solving open-ended problems related to arithmetic and geometric sequences. Analysis of student responses indicates fluency, flexibility, elaboration, and originality, reflecting the development of mathematical creativity.

Discussion

The findings of this study demonstrate that professional teachers' experiential Pedagogical Content Knowledge can be systematically transformed into a structured and effective mathematics learning model. The integration of curriculum alignment, understanding of student misconceptions, contextual worksheets, guided discovery, and authentic assessment forms a coherent instructional cycle grounded in PCK.

The model's effectiveness can be explained by the integration of the four PCK components. First, knowledge of students' misconceptions allowed teachers to design reflective preliminary activities that addressed conceptual obstacles in sequences and series. Second, instructional strategy knowledge enabled the use of guided discovery and open-ended problems, which encouraged conceptual construction rather than procedural memorization. Third, curriculum knowledge ensured alignment with competency standards. Fourth, assessment knowledge facilitated authentic evaluation of students' reasoning processes.

These results are consistent with the assertion that integrated PCK enhances learning effectiveness (Kultsum, 2017; Muhtarom et al., 2019; Purwoko et al., 2019; Van Driel & Berry, 2012). The findings also support (Bwalya & Rutegwa, 2023; Mishra, P., & Koehler, 2026), who reported that open-ended approaches promote students' mathematical creativity. How-

ever, unlike previous studies that primarily analyzed teachers' PCK levels (Awadh et al., 2023; Ekawati et al., 2022; Grigaliūnienė et al., 2025), this study operationalized PCK into a concrete instructional model specifically applied to sequences and series.

The main finding of this research is that professional teachers' experiential PCK can be transformed into a valid, practical, and effective mathematics learning model for teaching sequences and series. The model's success is influenced by the systematic integration of reflection, contextual problem-solving, guided discovery, and authentic assessment.

The strength of this study lies in its structured development process using the Plomp model and in the comprehensive testing of validity, practicality, and effectiveness. However, a limitation of this study is that the field implementation was conducted in a small number of schools and did not include a control group.

This study implies that professional teachers' knowledge should be systematically documented and structured into instructional models to improve the quality of mathematics learning, particularly for conceptually demanding topics such as sequences and series. This study contributes theoretically by demonstrating how PCK can be operationalized into a structured instructional framework and contributes practically by providing validated learning tools ready for classroom use.

CONCLUSIONS

This study concludes that the mathematics learning model developed based on teachers' Pedagogical Content Knowledge (PCK) is valid, practical, and effective for teaching sequences

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and series at the senior high school level. The main findings show that professional teachers' experiential PCK can be systematically transformed into structured learning instructions that meet validity and practicality criteria and achieve classical mastery above 75%, indicating improved students' understanding and creativity in sequences and series. These results confirm that a PCK-based learning model can serve as an alternative approach to enhance the quality of mathematics learning. It is suggested that future research involve broader samples and experimental designs with control groups to strengthen evidence of effectiveness, extend implementation to other mathematical topics, and examine its impact on higher-order thinking skills. Professional development support is also recommended to optimize teachers' implementation of PCK-based instructional models in classroom practice.

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