BUKTI KORESPONDENSI

ARTIKEL JURNAL TERINDEKS SINTA 2

Judul Artikel : Pedagogical Content Knowledge (PCK) of Prospective Science Teachers in ASEAN to ReSustainable Development Action

Nama Jurnal : Al-Jahiz: Journal of Biology Education Research (Sinta 2)

Nama Penulis : **Riska Septia Wahyuningtyas,** Manogari Sianturi, Elferida Sormin, Candra Ditasona, Santri Chintia Purba, Stevi Natalia, Merle L. Junsay, Rene Estomo, Hotmaulina Sihotang

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2	Bukti konfirmasi review dan hasil review	**23 Juli 2025**
3	Bukti resubmit hasil review dan artikel yang di resubmit	**16 September 2025**
4	Bukti konfirmasi artikel accepted dan masuk	**9 Desember 2025**
5	Bukti artikel terpublikasi secara online dan artikel yang dipublikasi	**9 Desember 2025**

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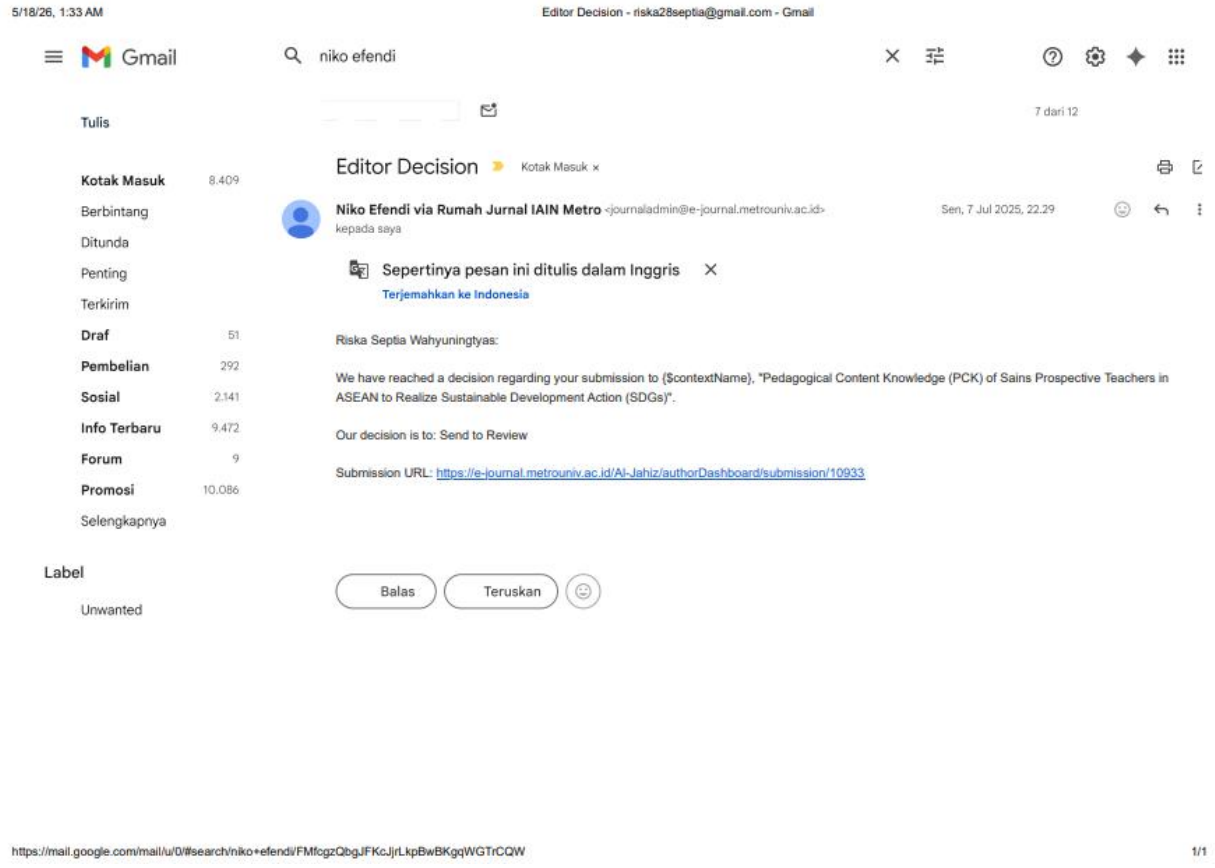

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Pedagogical Content Knowledge (PCK) of Prospective Science Teachers in ASEAN to Realize Sustainable Development Action

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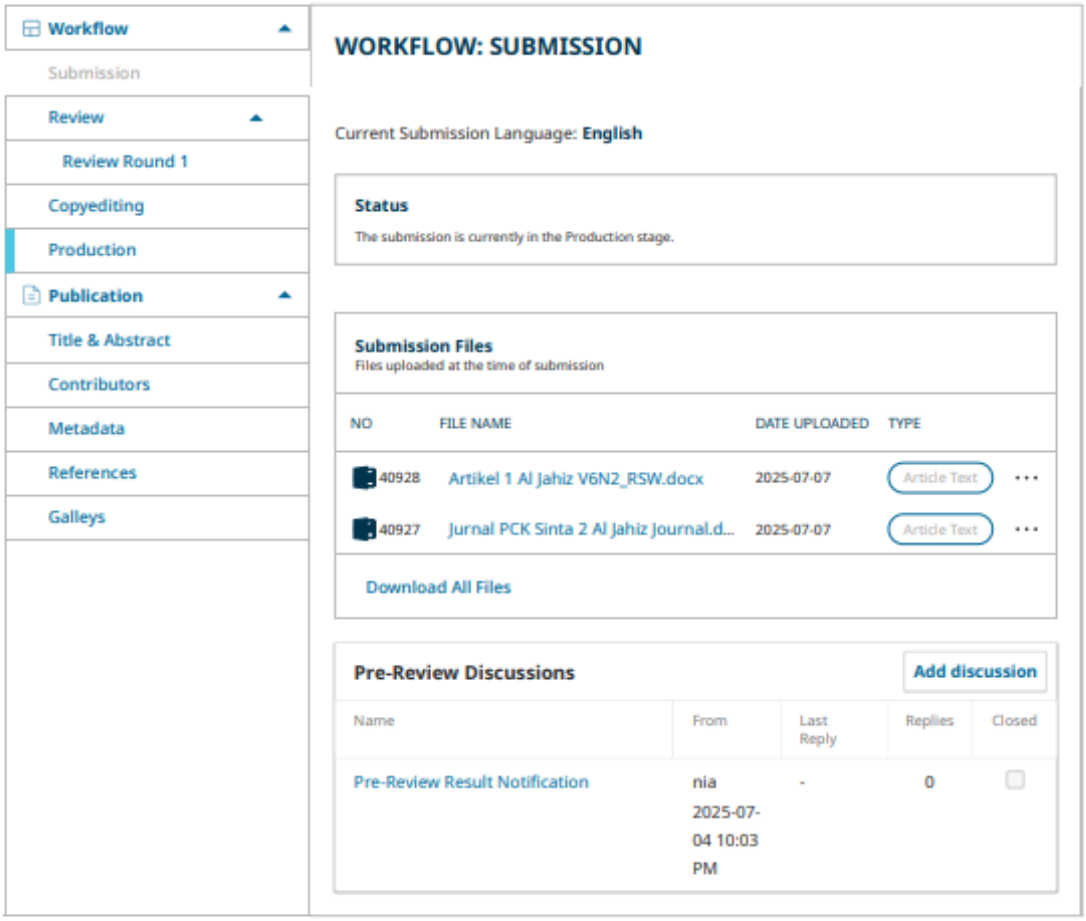

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- Workflow
  - Submission
  - Review
    - Review Round 1
  - Copyediting
  - Production
- Publication
  - Title & Abstract
  - Contributors
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  - Galleys

WORKFLOW: REVIEW (ROUND 1)

Current Submission Language: **English**

Status

The submission is currently in the Production stage.

Notifications

Editor Decision	2025-07-07 10:29 PM
Editor Decision	2025-07-23 06:54 PM
Editor Decision	2025-12-09 02:26 AM

Revisions Uploaded

These files have been submitted by the author after revisions were requested

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44368	Jurnal PCK Sinta 2 Al Jahiz Journal r...	2025-12-06	Article Text
43160	Revisi 3 Jurnal PCK Sinta 2 Al Jahiz J...	2025-11-01	Article Text
42713	Jurnal PCK Sinta 2 Al Jahiz Journal R...	2025-10-12	Article Text
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A message regarding Al Jahiz: Journal of Biology Education Research	niko12 2025-12-01 07:52 PM	-	0	

Gmail riska septia wahyuningtyas <riska28septia@gmail.com>

Editor Decision

1 pesan

Niko Efendi via Rumah Jurnal IAIN Metro <admin@e-journal.metrouniv.ac.id> 23 Juli 2025 pukul 18.54
Balas Ke: Niko Efendi <1801061023@metrouniv.ac.id>
Kepada: Riska Septia Wahyuningtyas <riska28septia@gmail.com>

Riska Septia Wahyuningtyas:

We have reached a decision regarding your submission to {$contextName}, "Pedagogical Content Knowledge (PCK) of Sains Prospective Teachers in ASEAN to Realize Sustainable Development Action (SDGs)".

Our decision is: Revisions Required

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Gmail riska septia wahyuningtyas <riska28septia@gmail.com>

A message regarding Al Jahiz: Journal of Biology Education Research

1 pesan

Niko Efendi <rumahjurnal@metrouniv.ac.id> 1 September 2025 pukul 19.58
Kepada: Riska Septia Wahyuningtyas <riska28septia@gmail.com>

Dear Ms. Riska Septia Wahyuningtyas,

I hope this message finds you well.

This is a friendly reminder regarding your manuscript entitled: **"Pedagogical Content Knowledge (PCK) of Science Prospective Teachers in ASEAN to Realize Sustainable Development Action (SDGs)"**

We kindly ask you to submit the revised version of your manuscript by addressing the reviewers' comments to improve the quality of the paper. Please upload the revised file through the journal website. If, however, you encounter any technical difficulties with the system, you are welcome to send the revised manuscript directly via email as an alternative.

To keep the review process on schedule, we would greatly appreciate it if you could submit the updated version no later than **15 September 2025**.

Should you need any clarification or assistance, please do not hesitate to contact us.

Thank you very much for your kind cooperation and valuable contribution.

Kind regards,

Niko Efendi

Section Editor

Al Jahiz: Journal of Biology Education Research

—
Reply to this comment at #10933 Wahyuningtyas or unsubscribe from emails sent by Al Jahiz: Journal of Biology Education Research.

Revisi 2

Gmail **riska septia wahyuningtyas <riska28septia@gmail.com>**

Re: A message regarding Al Jahiz: Journal of Biology Education Research

1 pesan

Niko Efendi <rumahjurnal@metrouniv.ac.id> 26 September 2025 pukul 21.25
Kepada: Riska Septia Wahyuningtyas <riska28septia@gmail.com>

Dear Ms. Riska Septia Wahyuningtyas,

Thank you for submitting the revised version of your manuscript titled *"Pedagogical Content Knowledge (PCK) of Sains Prospective Teachers in ASEAN to Realize Sustainable Development Action (SDGs)."*

We appreciate the revisions you have made in response to the reviewers' comments. Upon editorial review, we noted that revisions have been made; however, please ensure that the revised manuscript does not exceed 20 pages in total, including the reference list. We kindly ask that you streamline the content where necessary, while keeping the main objectives and contributions of your research clearly presented.

Due to file size limitations, the detailed annotated notes could not be uploaded to the system. We have therefore sent the document with editorial notes to your registered email address. Please kindly check your inbox for the file.

We kindly ask that you submit your revised manuscript no later than **12 October 2025, 23:59 (WIB).**

Should you have any questions or need clarification, please do not hesitate to contact us. We appreciate your continued commitment to the review process and look forward to receiving your updated submission.

Best regards,
Niko Efendi
Editor
Al Jahiz: Journal of Biology Education Research

—

Revisi 3

Gmail riska septia wahyuningtyas <riska28septia@gmail.com>

Re: A message regarding Al Jahiz: Journal of Biology Education Research

1 pesan

Niko Efendi <rumahjurnal@metrouniv.ac.id> 11 November 2025 pukul 12.42
Kepada: Riska Septia Wahyuningtyas <riska28septia@gmail.com>

Dear Ms. Riska Septia Wahyuningtyas,

Thank you for submitting the revised version of your manuscript titled **"Pedagogical Content Knowledge (PCK) of Prospective Science Teachers in ASEAN to Realize Sustainable Development Action (SDGs)."** We appreciate your efforts in addressing the reviewers' comments. Several parts have improved; however, further refinement is still required to ensure clarity, coherence, and alignment with the study's objectives.

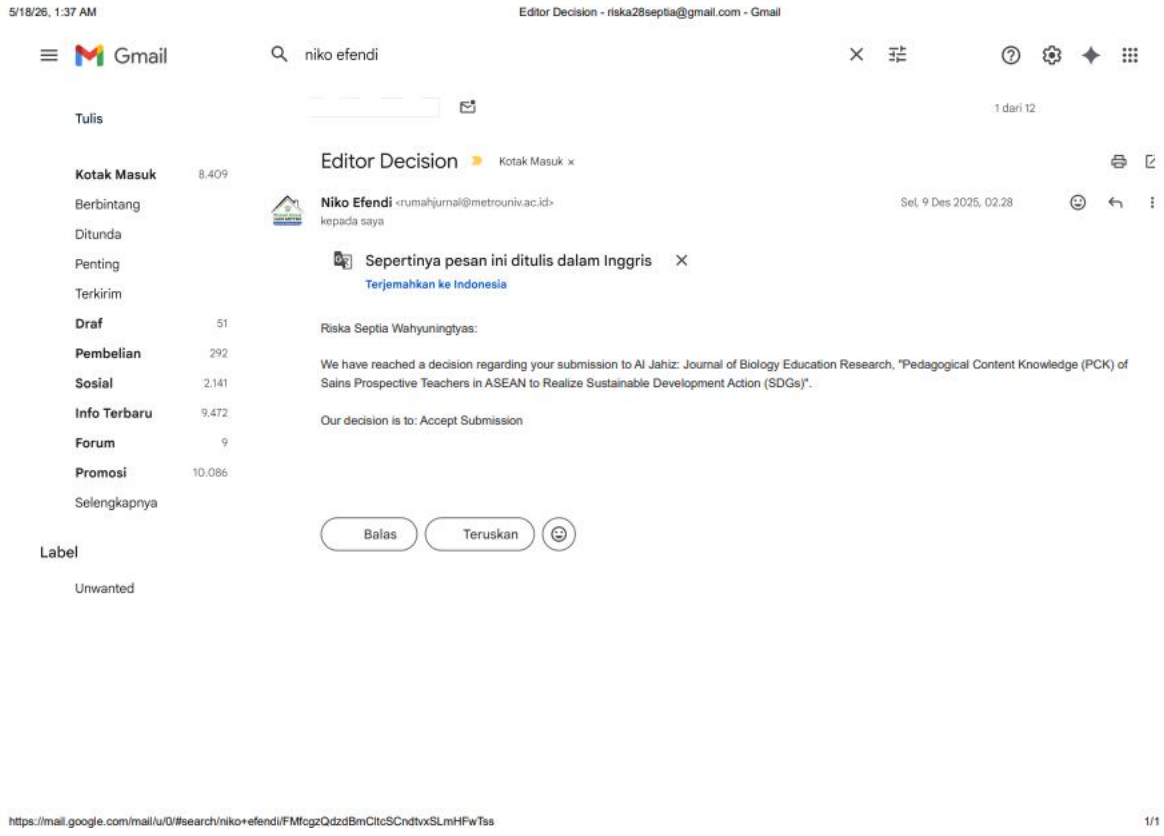
Please also update your references with more recent and relevant sources, and carefully review whether all reviewers' comments have been fully addressed. Due to file size limitations, the detailed annotated notes could not be uploaded to the system. We have therefore sent the document with editorial notes to your registered email address. **Please kindly check your inbox for the file.**

Please submit the revised manuscript by **30 November 2025, 23:59 (WIB).**
Additionally, please ensure that the file size is optimized or compressed before uploading, so that it can be accessed and uploaded easily through the journal's submission system.

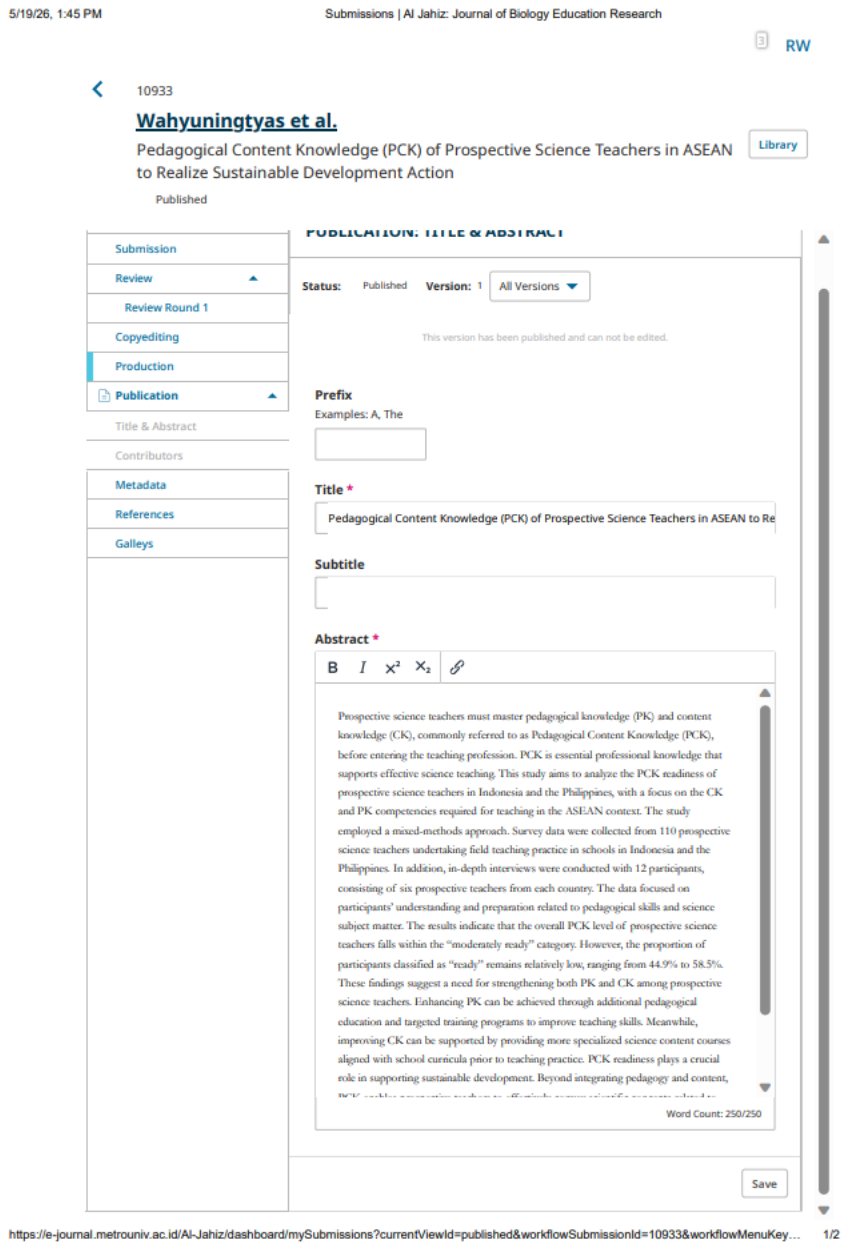
Best regards,
Niko Efendi
Editor
Al Jahiz: Journal of Biology Education Research

—
Reply to this comment at #10933 Wahyuningtyas or unsubscribe from emails sent by Al Jahiz: Journal of Biology Education Research.

Bukti Accept Submission



Publikasi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Pedagogical Content Knowledge (PCK) of Prospective Science Teachers in ASEAN to Re
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Abstract *
Prospective science teachers must master pedagogical knowledge (PK) and content knowledge (CK), commonly referred to as Pedagogical Content Knowledge (PCK), before entering the teaching profession. PCK is essential professional knowledge that supports effective science teaching. This study aims to analyze the PCK readiness of prospective science teachers in Indonesia and the Philippines, with a focus on the CK and PK competencies required for teaching in the ASEAN context. The study employed a mixed-methods approach. Survey data were collected from 110 prospective science teachers undertaking field teaching practice in schools in Indonesia and the Philippines. In addition, in-depth interviews were conducted with 12 participants, consisting of six prospective teachers from each country. The data focused on participants' understanding and preparation related to pedagogical skills and science subject matter. The results indicate that the overall PCK level of prospective science teachers falls within the "moderately ready" category. However, the proportion of participants classified as "ready" remains relatively low, ranging from 44.9% to 58.5%. These findings suggest a need for strengthening both PK and CK among prospective science teachers. Enhancing PK can be achieved through additional pedagogical education and targeted training programs to improve teaching skills. Meanwhile, improving CK can be supported by providing more specialized science content courses aligned with school curricula prior to teaching practice. PCK readiness plays a crucial role in supporting sustainable development. Beyond integrating pedagogy and content,
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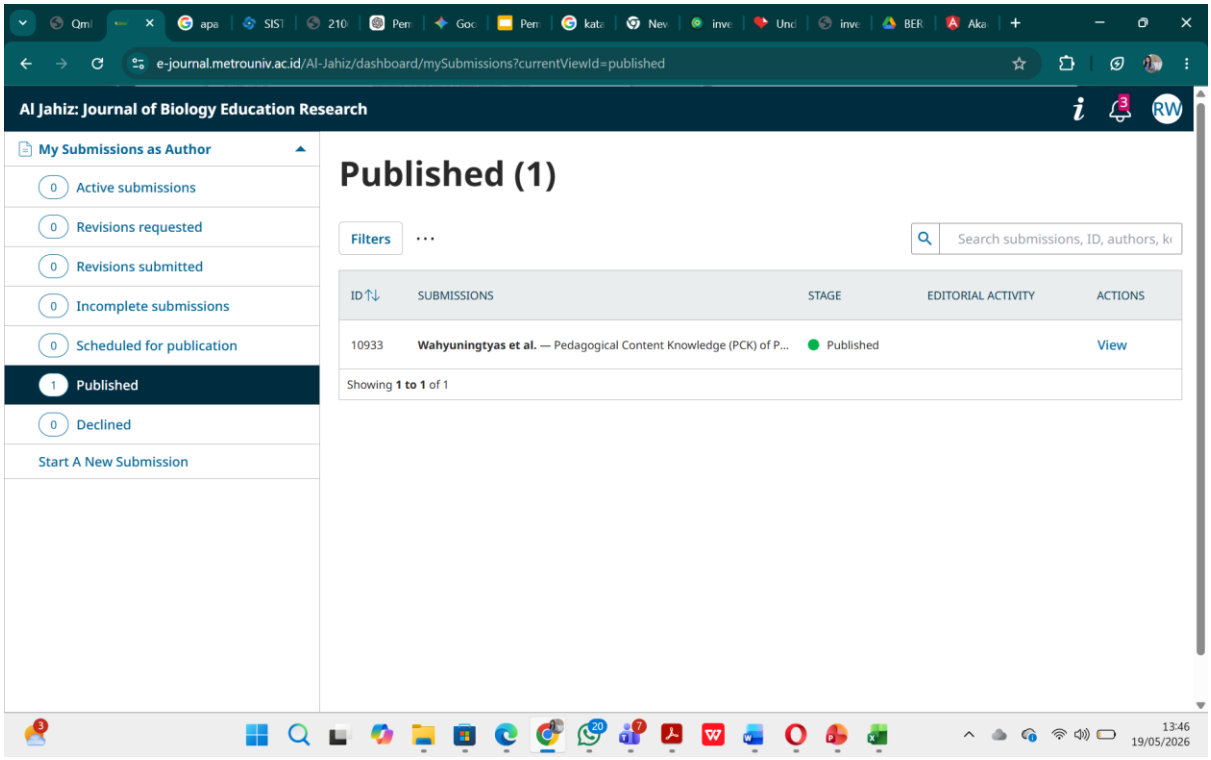
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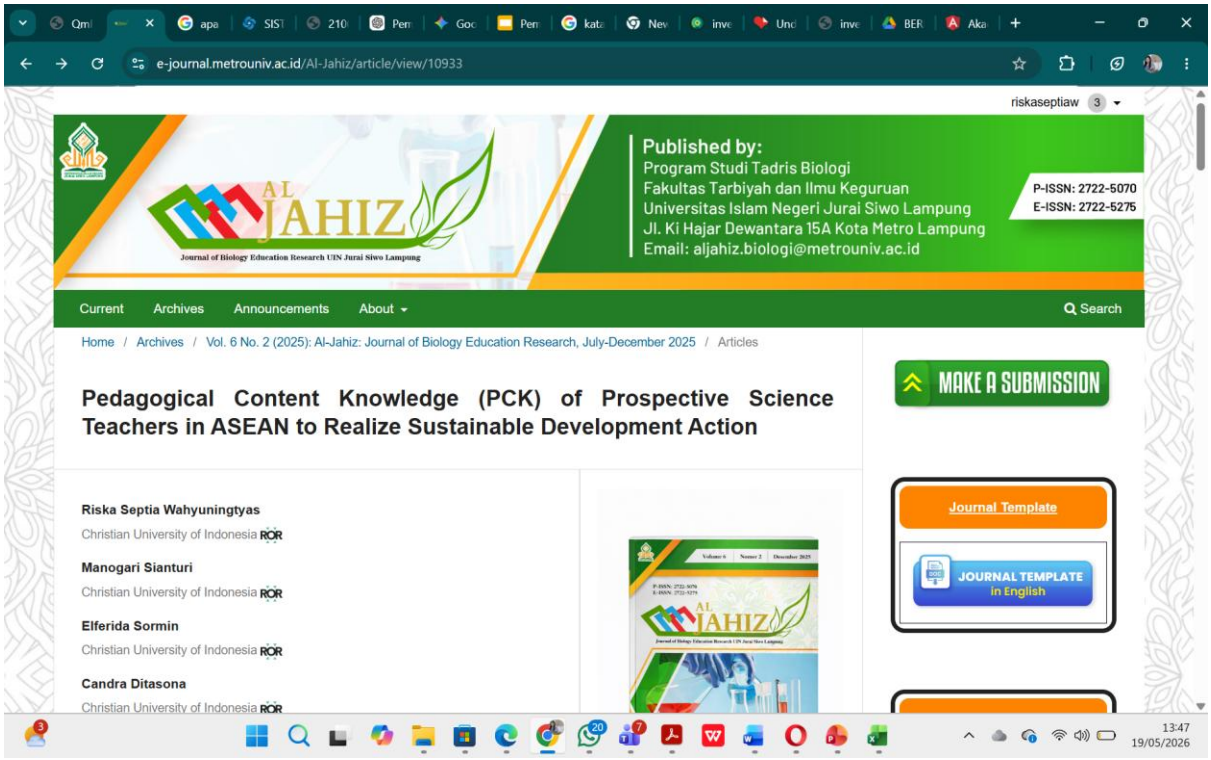
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Pedagogical Content Knowledge (PCK) of Prospective Science Teachers in ASEAN to Realize Sustainable Development Action
Riska Septia Wahyuningtyas
Christian University of Indonesia
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Hasil Review dari Jurnal

Review Result

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INTRODUCTION SECTION

1. Background Clarity and Sufficiency

The introduction provides a general overview of educational changes and the importance of Pedagogical Content Knowledge (PCK) for prospective science teachers. However, the background lacks a sharply defined research problem. For example:

"Education is a field of work that will be engaged in by prospective science teachers."

This sentence is too general and does not establish a clear research urgency or problem.

2. Absence of Preliminary Studies or Literature-based Foundation

The introduction does not clearly present preliminary studies, whether from observations, surveys, or literature reviews. While it does reference theoretical works (e.g., Shulman 1986, 1987), they are not framed as a foundation for the current research context.

"Pedagogical Content Knowledge (PCK) according to Shulman (1987)..."

This statement introduces theory but not empirical studies or literature trends that justify the relevance of this study.

3. Gap Analysis (Novelty Clarification)

The research gap is not explicitly articulated. The introduction fails to highlight what existing research lacks, especially in terms of comparative PCK analysis across ASEAN countries (Indonesia vs. the Philippines).

"The readiness of prospective teachers in terms of PCK will be very important to know..."

While this signals importance, it does not explain what past studies have overlooked, e.g., regional comparisons, SDGs integration, or readiness level quantification.

Recommendation:
Add a paragraph that clearly contrasts this study with existing literature.

4. Research Positioning (Attitude toward Previous Studies)

The author's stance toward previous research is not stated. There is no indication whether this study seeks to support, contradict, or refine existing findings on PCK.

Recommendation:
Include a sentence such as:

"This study supports the framework established by Shulman (1987), but also challenges the assumption that pre-service teachers are adequately prepared to integrate sustainability concepts into science teaching."

5. Transition to Research Objectives

The purpose of the research is mentioned too early without proper buildup from the literature or problem analysis. This comes before the reader understands what research has or has not covered, and why this specific readiness needs to be studied.

Recommendation:
Move this purpose statement after the gap analysis and justification, ensuring it logically follows the identified problem and knowledge void.

RESEARCH METHODS SECTION

1. Quantitative and Qualitative Descriptions

- Please describe Quantitative and Qualitative more detailed.
- Please provide a description of how the quantitative and qualitative data were analyzed (e.g., descriptive statistics, inferential statistics, t-test, ANOVA, etc.).

2. Research Subjects and Sample

Please include a more detailed description of the subject characteristics, the rationale for selecting purposive sampling, and steps to minimize bias between groups.

3. Instrument Development and Validation Procedures

Please describe the technical information related to the instrument's validity and reliability testing, and cite the validation standards used.

5. Data Analysis

Please clarify the technical data analysis procedures and place the results of the normality/homogeneity tests in the "Research Results" section, not in the methods section.

RESEARCH RESULT SECTION

1. Qualitative Results Not Displayed

There was no section containing qualitative results, even though the research design stated that qualitative follow-up would be used to further explore the quantitative results.

"Qualitative investigations will continue after participants with the least, most, and moderate readiness are identified."

However, the results of the interviews with six prospective teachers in each country were not explained, either in the form of quotes, themes, or visualizations (e.g., a thematic model or matrix).

2. Readiness Categorization Is Not Based on Scientific Criteria

There is no explanation regarding the cut-off scores or quantitative indicators for the categories "Ready," "Moderately Ready," and "Not Ready."

This poses a methodological issue because, without transparency about the categorization boundaries, readers cannot verify the validity of the classification.

"*Students who are quite ready... have not mastered the indicators that must be achieved in science knowledge material.*"

However, the indicators or scoring in question are not specified.

3. Descriptive Without Statistical Test

There is no test of intergroup differences (e.g., a chi-square test or t-test) that is actually important in comparing two different groups (Indonesia and the Philippines).

In fact, quantitative methods have the potential to answer the following questions:

- Are the differences in readiness percentages significant?
- Are the PK and CK variables correlated with PCK?

DISCUSSION SECTION

1. The Discussion Does Not Analyze the Data Results in Depth

Although the major themes of the research have been explained, but there has been no critical discussion of the differences in the data between Indonesia and the Philippines.

2. The discussion section does not refer back to the Mixed Methods Methodology

The methodology used is explanatory sequential mixed methods, but the discussion does not mention the role of qualitative data (which is also not presented in the results).

There is no explanation of how qualitative data was used to enrich or clarify the quantitative results. As a result, the discussion focuses solely on the interpretation of quantitative data, making the contribution of qualitative data to explaining the phenomenon less visible.

3. The discussion section does not involve much literature or previous studies

The discussion still predominantly consists of paraphrasing the results and re-explaning concepts, without explicitly comparing them with the findings of other previous studies. Yet, the reference section contains numerous sources that could be used for comparative discussion.

4. The discussion section, there is no confirmation of practical implications.

The discussion does not explicitly answer the questions:

- What are the implications of these findings for teacher education programs?
- How can these results inform policy recommendations or curriculum improvements?

CONCLUSION SECTION

The CONCLUSION section is quite relevant in content to the data and discussion, but it does not reflect the methodological strength promised in mixed methods, particularly in its statement regarding the contribution of qualitative data to the research. It also does not explicitly convey scientific novelty and practical impact. Methodological reflections, educational implications, and theoretical contributions are needed to make the conclusions truly comprehensive and representative.

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Pedagogical Content Knowledge (PCK) of Sains Prospective Teachers in ASEAN to Realize Sustainable Development Action (SDGs)

Commented [u1]: The use of the word ASEAN needs to be considered, because it only involves 2 countries.

Commented [u2]: This phrase seems ambitious and normative, while in the article there are no specific empirical indicators about SDGs action, SDGs integration is only explained narratively, not as a measurable variable.

Double-blind review

Double-blind review

*Coresponding author : Double-blind review

Informasi artikel

Riwayat artikel:
Diterima:
Direvisi:
Dipublikasi:

Kata kunci:
ASEAN
PCK
Readines
Student
Sains Teacher
SDGs

ABSTRAK

Calon guru IPA sangat penting untuk memiliki penguasaan terkait pengetahuan pedagogis (PK) dan pengetahuan material (CK) terkait materi IPA atau yang biasa kita kenal dengan Pengetahuan Konten Pedagogis (PCK) sebelum terjun ke dunia kerja. PCK merupakan pengetahuan wajib yang harus dikuasai oleh calon guru. Penelitian ini bertujuan untuk menganalisis kesiapan PCK bagi calon guru IPA di Indonesia dan Filipina. Penelitian ini akan menjelaskan terkait CK dan PK yang harus dikuasai oleh guru yang akan mengajar di kawasan ASEAN. Data ini dikumpulkan dengan melakukan survei terhadap 110 calon guru yang sedang melakukan praktik lapangan di sekolah-sekolah di Filipina dan Indonesia. Data juga diperkuat dengan melakukan wawancara dengan 6 calon guru di Indonesia dan 6 calon guru di Filipina. Data yang dikumpulkan terkait dengan apa yang mereka pahami dan siapkan dari segi pedagogi dan materi sains. Hasil penelitian ini menunjukkan bahwa kemampuan PCK mereka rata-rata pada level ready. Temuan penelitian ini menunjukkan bahwa guru harus meningkatkan pengetahuannya terkait pengetahuan muatan pedagogis (PCK) karena jumlah siswa sebagai calon guru IPA yang berada dalam kategori siap masih relatif rendah, yakni 44,9 -58,5%. Peningkatan PK dapat dilakukan dengan memberikan tambahan kursus pendidikan dan pelatihan pedagogis untuk meningkatkan keterampilan pedagogis. Peningkatan CK dapat dilakukan dengan menambahkan mata kuliah khusus untuk materi IPA di sekolah sebelum mereka berlatih mengajar ke sekolah. Kesiapan calon guru IPA dalam memahami Pedagogical Content Knowledge (PCK) berperan penting dalam mendukung aksi pembangunan berkelanjutan. PCK tidak hanya mencakup kemampuan calon guru untuk mengintegrasikan pengetahuan bahan ajar dan strategi pedagogis, tetapi juga kemampuan mereka dalam menyampaikan konsep ilmiah yang relevan dengan isu keberlanjutan, seperti perubahan iklim, konservasi sumber daya alam, dan teknologi ramah lingkungan.

Keywords:
ASEAN
PCK
Readines
Student
Sains Teacher
SDGs

ABSTRACT

Prospective science teachers are very important to have mastery related to pedagogical knowledge (PK) and material knowledge (CK) related to Science or what we commonly know as Pedagogical Content Knowledge (PCK) before entering the world of work. PCK is mandatory knowledge that must be mastered by prospective teachers. This study aims to analyze the readiness of PCK for prospective science teachers in Indonesia and the Philippines. This research will explain related to CK and PK that must be mastered by teachers who will teach in the ASEAN region.

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This data was carried out by conducting a survey of 110 prospective teachers who are conducting field practice in schools in the Philippines and Indonesia. Data was also collected by conducting interviews with 6 prospective teachers in Indonesia and 6 prospective teachers in the Philippines. The data collected is related to what they understand and prepare in terms of pedagogy and science materials. The results of this study showed that their PCK ability was average at the ready level. The findings of this study show that teachers must improve their knowledge related to pedagogical content knowledge (PCK) because the number of students as prospective Science teachers who are in the ready category is still relatively low, namely 44,9 - 58,5%. Improving PK can be done by providing additional pedagogical education and training courses to improve pedagogical skills. Improving CK can be done by adding special courses for Science material in schools before they practice teaching to schools. The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies.

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INTRODUCTION

Education is a field of work that will be engaged in by prospective science teachers. Education includes teacher teaching activities and student learning activities. The new era of education in the current school curriculum is centered on student center learning. Students are not required to have good learning results to get first place, but students are required to master a good learning process. In order for students to obtain a good learning process, a teacher must understand how to teach and how to make students understand the material by doing activities or practicums. The material received by students from year to year will change along with the development of the times and technology, so that in this new era of education students are not required to only master the material but must be able to do activities to find a material.

The dynamic development of science in accordance with the development of the times makes teachers always have to be creative in making learning activities. Learning activities must be adjusted to the demands of the times. To answer this, it is very important for teachers to master classroom management and the development of ever-changing materials that will be given to

Commented [u3]: This sentence is too general and **does not establish a clear research urgency** or problem.

Recommendation:
Replace general statements with more **problem-focused descriptions**. For instance, the authors could begin by emphasizing specific challenges in science education across ASEAN, such as the disparity in teacher readiness for SDGs integration.

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students. This is in accordance with the theory that states that the challenge to prepare for future life is by learning 21st century skills where children will be faced with uncertain situations in the future (Hong et al., 2019). Uncertainty in the future is related to the material that students will receive that is always changing and evolving. Changes in the material received by students must be in line with changes in the way a teacher teaches. If the change in material is taught in the way of teaching in the past, for example lectures, then students will not understand and learning does not make students actively search for the material themselves.

Pedagogical Content Knowledge (PCK) according to Shulman (1987) is to characterize teachers' knowledge to instructional explicitly with integrated pedagogy and content as well. PCK contains two main components, namely Content Knowledge (CK) and Pedagogical Knowledge (PK). First, CK describes the knowledge of prospective teachers regarding the subject matter of the material to be taught. Knowledge of this content is one of the most important components as a requirement to become a teacher (Shulman, 1986). Second, PK describes the knowledge of prospective teachers about mastery of practices, processes, strategies, procedures, and methods in the teaching and learning process (Shulman, 1986).

Commented [u4]: Please provide brief results or findings from previous studies or reports on PCK readiness among science teachers in an ASEAN or global context. This will strengthen the argument that the study addresses a real and recognized issue.

PCK merupakan ilmu penting yang harus dikuasai oleh calon guru sebagai dasar untuk membantu dan making it easier for students to understand difficult concepts. PCK can also improve knowledge and skills including critical thinking, creativity, communication and collaboration skills (Cetin-Berber, D. & Erdem, A, 2015). Teachers who master PCK are believed to be able to create a fun learning atmosphere and make it easier for students to understand the material.

Commented [u5]: Please pay attention to consistency in the use of language.

PCK is an idea where the delivery of material must be adjusted to the teacher's teaching method which is not monotonous and always changes every meeting. For example, the first day with the docovery learning model, the second day with the project-based learning model, and the third day with the cooperative learning model. Changes in teaching methods will make students interested in starting learning activities. Students will always want to know what new learning activities the teacher uses in each of their meetings. If the motivation of students in participating in learning activities has appeared, the learning material will be very easy for students to accept. PCK plays a very effective role in teacher development to achieve effective learning activities.

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Pedagogical knowledge includes mastery of student characteristics, mastery of learning theories and principles of educational learning, curriculum development, educational learning activities, development of student potential, how to communicate, and mastery of student assessment and evaluation. Pedagogic competence includes 10 standards, namely 1) mastery of students' character. 2) understanding related to learning theories 3) being able to develop a curriculum. 4) carrying out development activities. 5) Utilizing technology for learning media. 6) providing facilities for the development of students' potential. 7) communicate effectively, empathetic and polite to students. 8) conduct assessments and evaluations of learning processes and outcomes. 9) utilizing the results of assessment and evaluation. 10) Carrying out reflective actions in improving the quality of teaching and learning (Kementerian Pendidikan Nasional Indonesia, 2007).

Philippines is a country that prioritizes teachers who have good pedagogical skills. Government regulations in the Philippines are also clear that there are 7 main domains for a teacher to be effective in organizing learning according to the demands of education in the 21st century. Qualified teachers in the Philippines need to possess the following characteristics: recognize the importance of mastery of content knowledge and its relevance within and across curriculum areas; provide a safe, secure, fair and supportive learning environment to increase student responsibility and achievement; building a learning environment that is responsive to the diversity of students; interact with national and local curriculum requirements; implementing various assessment tools and strategies in monitoring, evaluating, documenting and reporting on students' needs, progress and achievements; establishing school-community partnerships that aim to enrich the learning environment, as well as community involvement in the educational process; Valuing personal growth and professional development and showing high personal respect for their profession by maintaining qualities that uphold the dignity of teaching such as caring, respectful and integrity (Philipines DepEd Order Number. 42, s, 2017).

A good teacher is a teacher who can involve students in all learning activities in the classroom. Teachers must understand the 10 pedagogic competency standards so that learning activities are more meaningful. PCK is knowledge about the pedagogical relationship with the learning materials that will be given to students. PCK is a basic ability for teacher ability development. The development of teachers in Indonesia is supported by teacher professional

education (PPG) which must be pursued by education graduates. Teachers are expected to develop into a profession that can support 21st century skills and the development of technological advances by creating quality students. The concept of teacher education focuses on technology education that is integrated in PCK or pedagogical content knowledge (Shulman, 1986). Learning practices use PCK to acquire the knowledge and skills students need that are relevant to the content, culture, context and psychological role (Denby, D, and Holman, J , 2002). PCK is a science that really helps teachers to create a common ground between the material to be delivered at school, the content of learning, and pedagogical competence. Nuangchalerm (2020) shows that PCK can help teachers learn to be good at teaching and better understand pedagogical skills. Teachers who already know the content of the material must think about what learning model is suitable for use in learning activities so that all students can be active.

Science is a material that really needs a variety of learning models to make students understand the material. Prospective science teachers must be able to understand pedagogical skills and use these skills to teach a wide variety of science materials. The readiness of prospective teachers in terms of PCK will be very important to know to be able to find problems related to this. This research will be very important to produce conclusions related to the condition of prospective science teachers in Indonesia and the Philippines to find out the PCK. According to Shulman (1987), teacher preparation programs must combine pedagogical knowledge and content knowledge to teach and learn appropriately. PCK is the ability to combine knowledge of a particular discipline with science teaching. This makes teachers really understand the content and turn it into appropriate teaching (Shulman, 1986). Students who are interested in learning activities will also begin to be interested in learning the material. The combination of fun learning activities and the material taught will be easily accepted by students if their hearts are happy.

Heibert et al (2007) proposed a teacher preparation framework to help develop teacher competencies in setting learning objectives, evaluating student performance, hypothesizing the relationship between learning materials and self-reflection teaching. Social changes and learning environments are pushing the trend of PCK to a higher level of use (Nuangchalerm, 2020). PCK is a science that must be mastered by prospective teachers to develop skills and professionalism in teaching. The combination of 2 elements, namely pedagogy and material content, is very basic so that teachers can work professionally. This study aims to analyze PCK in ASEAN education and

connect PCK with prospective science teachers. The results of this research will be used as input for the Teacher Professional Education program in Indonesia and Philippines. The results of this research are also expected to be an input for universities to provide further knowledge related to PCK by combining it in courses.

Teachers in the future need to master a good understanding of how pedagogical knowledge and content can be effective in the learning process in the classroom. To answer this need, Koehler and Mishra (2019) introduced a conceptual framework called Pedagogical Content Knowledge (PCK) which was obtained from the addition of technology to Pedagogical Content Knowledge (PCK) which is a conceptual framework built by Shulman (1986). According to Karaca (2015), the development of the PCK model provides an overview for prospective teachers and academics that the model can help improve the ability to integrate technology in the learning process in the classroom to find out the latest material content. PCK as a relationship between pedagogical knowledge and content that is the basis of good teaching.

The content of the material that is interacted with good pedagogical skills will be able to help solve the problems faced by students in carrying out effective, innovative and fun learning. The integration of pedagogical skills in the delivery of teaching materials requires a structured and creative design in its application, in addition to that, the right approach is also needed in the learning implementation plan with the context of the material to be delivered. This PCK knowledge will be very meaningful for prospective teachers to form a teaching activity when they have entered the world of work.

The Sustainable Development Goals (SDGs) are a global agenda launched by the United Nations (UN) to achieve inclusive, sustainable, and environmentally sound development (Kleespies & Dierkes, 2022; Whittingham et al., 2023). The SDGs in goal no. 4 emphasize the importance of providing quality education that reaches all levels of society. SDGs-oriented education aims to equip students with knowledge, skills, values, and attitudes that support the achievement of sustainable development. This includes awareness of global issues, such as climate change, gender equality, social justice, and environmental conservation.

The implementation of the SDGs in learning is essential to ensure that future generations not only become academically competent individuals, but also socially and ecologically responsible.

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Therefore, teachers have a central role in integrating SDGs values into the learning process. Teachers are expected to be able to design learning tools that are relevant to SDGs issues, so that students can understand and apply these concepts in real life. However, the success of the integration of SDGs in learning is highly dependent on the readiness of teachers' pedagogical content knowledge (PCK). PCK is a framework that includes knowledge of the content to be taught, effective pedagogical strategies, and an understanding of students' needs and characteristics. In the context of implementing the SDGs, teachers' PCK must include the ability to identify learning topics relevant to the SDGs, develop teaching methods that motivate students to think critically and act solutive on global issues, and develop learning evaluations that can measure students' understanding of SDGs issues.

Teachers' PCK readiness is a crucial aspect because not all teachers have adequate competence and experience in integrating the SDGs into the SDGs learning tools. For this reason, training and professional development for teachers is a necessary step. This training must include an in-depth understanding of the SDGs, innovative teaching strategies, and assessment techniques that support SDGs-based learning. Thus, teachers can be more confident and skilled in designing learning that not only prioritizes academic achievement, but also shapes the character of students with a global perspective.

RESEARCH METHOD

This study will use the research design of the explanatory sequential mixed method. The design of the sequential mixed method of explanation (also called the two-phase model; J. W. Creswell & Clark (2017) consists of first quantitative data collection and then qualitative data collection to help explain or elaborate the quantitative results. The reason for this approach is that the quantitative data and results provide an overview of the research problem; Further analysis, particularly through qualitative data collection, is necessary to refine, expand, or explain the general quantitative picture (Creswell, J., & Guetterman, 2018). The respondents of this study are students who will become prospective science teachers in 2 countries. The respondents consisted of 41 Indonesian students and 69 Philippines citizens.

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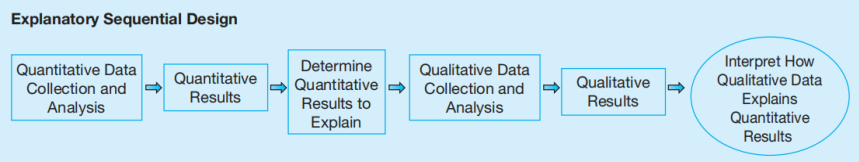

Figure 1. Explanatory Sequential Design

The analysis will be carried out in such a way that a quantitative investigation will be carried out first and then a qualitative investigation will follow. Quantitative inquiries will be used to collect information about the readiness of prospective teachers in terms of technological readiness, pedagogy, and content knowledge. Qualitative investigations will continue after participants with the least, most, and moderate readiness are identified.

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RESULT

This research was conducted in two countries. These countries are Indonesia and the Philippines. The results of the research that we present also involve data from 2 countries. The results of this study will describe the condition of knowledge pedagogy readiness and knowledge content in Indonesia and the Philippines.

Table 1. Level of PK (Pedagogical Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	42	60.9	35	85.4
Moderately Ready	26	37.7	6	14.6
Not Ready	1	1.4	0	0
N=	69	100.0	41	100.0

Table 1 shows that from the Philippines there are 42 students who are ready to master pedagogical skills and apply pedagogical knowledge to the classroom, while in Indonesia there are 35 students who are in the ready category. Students who are quite ready to understand pedagogy from the Philippines are 26 people while Indonesia is 6 people. This fairly ready category shows that students have not mastered too many indicators that must be achieved in Pedagogy. The pedagogical knowledge assessed in this study is to see how to assess student performance in the

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classroom, how to teach, my teaching style for diverse students, how teachers use various teaching approaches, how to overcome student misunderstandings, how to manage the classroom, and how to adapt the learning approach to the student's condition.

Table 1 above explains about students who belong to the group that are not prepared for mastering pedagogical knowledge. There is 1 student from the Philippines who is still not ready to master pedagogical knowledge while from Indonesia there are no students who are in the category of not ready. The lack of pedagogical science means that students do not know much about how to teach, how to assess, how to make school administration. Overall, the results of this study reflect that 85.4% of Indonesian students and 60.9% of Filipino students who will work as prospective science teachers have readiness in pedagogical skills. Meanwhile, 14.6% of Indonesian students and 37.7% of Filipino students are in the fairly ready category. The category of students from the Philippines who do not have the readiness to master pedagogical knowledge is 1.4%.

Pedagogical Knowledge (PK) is the knowledge possessed by a teacher about effective learning principles, methods, and strategies. The indicators of Pedagogical Knowledge include several main aspects that include the ability to understand learning theories, design learning, manage classrooms, conduct assessments, and utilize educational technology. Teachers who have a good PK are able to understand how students learn, choose methods that suit their learning needs, and create a classroom environment that is conducive to learning. One of the main indicators is the understanding of prospective teachers about the student learning process. It includes knowledge of cognitive development theories, learning styles, motivations, and diverse learning needs. In addition, the ability to design learning is also an important indicator. Prospective teachers must be able to make a Learning Implementation Plan that is in accordance with the curriculum, choose relevant learning methods, and determine measurable learning goals.

Table 2. Level of CK (Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	37	53.6	21	51.2
Moderately Ready	30	43.5	20	48.8
Not Ready	2	2.9	0	0
N=	69	100.0	41	100.0

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Table 2 shows that from the Philippines there are 37 students who are ready to understand the content of science material and implement science material that will be taught in class, while in Indonesia there are 21 students who are in the ready category. Students who are quite ready to understand the content of science material come from the Philippines totaling 30 people while Indonesia totals 20 people. This category of quite ready shows that students have not mastered the indicators that must be achieved in science knowledge material. The knowledge of the content of science material assessed in this study is that students have sufficient knowledge of physics, chemistry, biology. The second indicator is that students can integrate SETS (Science, Environment, Technology, and Society) in classroom learning. The third indicator is that students can match science material with the learning approach they want to use. The fourth indicator is that students can apply contextual learning, namely presenting science in real life. The fifth indicator is that students can apply their knowledge in the fields of Physics, Chemistry, and Biology and slice it into classroom learning. The eighth indicator is that students have extensive knowledge that is currently taught, namely biophysics, biochemistry, environmental balance, plants, animals, global warming.

Table 2 above also explains about students who belong to the unprepared group. There were 2 students from the Philippines while from Indonesia there were no students who were included in the unprepared category. The lack of pedagogy means that students do not know much about what science materials must be taught to students at school. In addition, they also lack understanding of the latest and current material that must be mastered if they want to become science teachers. Overall, the results of this study reflect that 53.6% of Indonesian students and 51.2% of Philippines students who will work as prospective science teachers have the readiness of science material content. Meanwhile, 48.8% of Indonesian students and 43.5% of Philippines students are in the category of being quite ready to know the content of science material. The category of students from the Philippines who are not ready is 2.9%.

Content knowledge (CK) includes an in-depth understanding of basic concepts in science, the ability to explain scientific phenomena, and the skill of integrating various branches of science such as physics, chemistry, biology, and earth science. CK is very important to ensure that

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prospective teachers are able to deliver material correctly, accurately, and relevantly. One of the main indicators of CK is mastery of basic concepts in science. Prospective teachers must understand the main principles in science, such as the laws of physics, chemical cycles, the structure and function of living things, and geological processes. This knowledge must be holistic, which means that prospective teachers are able to see the connections between branches of science to provide students with a complete picture of the world of science. Another indicator of a prospective teacher mastering content knowledge is that the teacher can explain and model scientific phenomena clearly and logically. Prospective science teachers must be able to use easy-to-understand language to explain abstract concepts to students. For example, explaining the concept of gravitational force or photosynthesis with concrete examples that are relevant to daily life. This ability also includes the use of visual aids or practicum to clarify explanations.

The readiness of content knowledge can also be assessed from the ability of prospective teachers to relate science knowledge to the context of real life and global issues. For example, prospective teachers must be able to relate science concepts to environmental issues, such as climate change, pollution, or the energy crisis. This indicator shows that prospective teachers not only understand the theory, but also its relevance to student life and the challenges of the modern world. CK readiness indicators also include reflective abilities and knowledge updates. Science is a field that continues to develop, so prospective teachers must have a commitment to continue learning, keep up with the development of science, and update teaching materials according to new findings. Based on the above, the readiness of prospective science teachers is not only measured by the extent to which they master the material, but also from their ability to teach the material in a relevant, interesting, and contextual way.

Table 3. Level of PCK (Pedagogical Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	31	44.9	24	58.5
Moderately Ready	34	49.3	17	41.5
Not Ready	4	5.8	0	0
N=	69	100.0	41	100.0

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PCK knowledge or Pedagogical Content Knowledge contains 2 major elements, namely pedagogical skills and knowledge of teaching materials. Table 3 above shows that from the Philippines there are 31 students and from Indonesia there are 24 students who are categorized as ready to know pedagogical skills and the implementation of pedagogical science into science materials that will be taught to students. Students who are quite ready to understand PCK from the Philippines are 34 people while Indonesia is 17 people. This category of sufficient readiness indicates that students have not mastered the indicators that must be achieved in the PCK assessment. The things assessed in this study include how students choose an effective teaching approach to guide students' thinking and learning on science materials, how to choose different learning models to teach various topics on science materials, and how to choose different learning methods to teach various topics in science materials. science material. Table 3 above also explains about students who belong to the unprepared group. There are 4 students from the Philippines while from Indonesia there are no students who are included in the category of not ready. Not ready in terms of PCK means that students do not know much about how to connect the learning approach with the teaching materials that will be delivered to students. Overall, the results of this study reflect that 44.9% of Indonesian students and 58.5% of Filipino students who will work as prospective science teachers have pedagogical readiness and science material content. Meanwhile, 41.5% of Indonesian students and 49.3% of Filipino students are included in the category of being quite ready to know pedagogical skills and the content of science materials. The category of students from the Philippines who are not ready is 5.8%.

The data above shows that practicum activities in learning have not been carried out perfectly by prospective science teachers in two countries. It can be seen that only 44.9% of prospective science teachers in the Philippines and 58.5% of science teachers in Indonesia are ready to understand Pedagogy and Material Material. Students who are ready are those who are worthy of teaching in the school. Other students who are not ready should be guided first and given training until they are ready and master the PCK to be able to enter school. Practice and learning materials seem to be less seen as an absolute requirement for students to be ready to teach and become prospective teachers in schools.

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DISCUSSION

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Pedagogical Knowledge (PK) is the knowledge possessed by a teacher about effective learning principles, methods, and strategies. The indicators of Pedagogical Knowledge include several main aspects that include the ability to understand learning theories, design learning, manage classrooms, conduct assessments, and utilize educational technology. Teachers who have a good PK are able to understand how students learn, choose methods that suit their learning needs, and create a classroom environment that is conducive to learning. One of the main indicators is the understanding of prospective teachers about the student learning process. It includes knowledge of cognitive development theories, learning styles, motivations, and diverse learning needs. In addition, the ability to design learning is also an important indicator. Prospective teachers must be able to make a Learning Implementation Plan that is in accordance with the curriculum, choose relevant learning methods, and determine measurable learning goals.

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Content knowledge (CK) includes an in-depth understanding of basic concepts in science, the ability to explain scientific phenomena, and the skill of integrating various branches of science such as physics, chemistry, biology, and earth science. CK is very important to ensure that prospective teachers are able to deliver material correctly, accurately, and relevantly. One of the main indicators of CK is mastery of basic concepts in science. Prospective teachers must understand the main principles in science, such as the laws of physics, chemical cycles, the structure and function of living things, and geological processes. This knowledge must be holistic, which means that prospective teachers are able to see the connections between branches of science to provide students with a complete picture of the world of science. Another indicator of a prospective teacher mastering content knowledge is that the teacher can explain and model scientific phenomena clearly and logically. Prospective science teachers must be able to use easy-to-understand language to explain abstract concepts to students. For example, explaining the concept of gravitational force or photosynthesis with concrete examples that are relevant to daily life. This ability also includes the use of visual aids or practicum to clarify explanations.

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The readiness of content knowledge can also be assessed from the ability of prospective teachers to relate science knowledge to the context of real life and global issues. For example, prospective teachers must be able to relate science concepts to environmental issues, such as climate change, pollution, or the energy crisis. This indicator shows that prospective teachers not only understand the theory, but also its relevance to student life and the challenges of the modern

world. CK readiness indicators also include reflective abilities and knowledge updates. Science is a field that continues to develop, so prospective teachers must have a commitment to continue learning, keep up with the development of science, and update teaching materials according to new findings. Based on the above, the readiness of prospective science teachers is not only measured by the extent to which they master the material, but also from their ability to teach the material in a relevant, interesting, and contextual way.

Understanding pedagogy or PK is a requirement so that students can choose the right learning strategy to teach the material. Understanding of teaching materials or CK is also a basic requirement so that students are ready to teach various materials that will be given at school according to their level. If PK and CK have not been mastered, what happens is that prospective teachers will always focus on the content and learning materials only and lack pedagogical strategies so that learning becomes boring because there are few student learning activities. Pedagogical Content Knowledge (PCK) is a combination of mastery of material (content knowledge) and the ability to teach it (pedagogical knowledge) effectively. PCK indicators include the ability of prospective teachers to understand the concept of teaching materials in depth, know the best way to deliver the material to students, and recognize the learning challenges faced by students. PCK integrates knowledge about "what is taught" and "how to teach" to make learning more effective and meaningful. The readiness of Pedagogical Content Knowledge of prospective teachers can be reviewed from several main indicators. First, the ability to identify important concepts in teaching materials that are often misconceptions for students. Prospective teachers must understand learning difficulties that may arise and be able to design learning strategies that can overcome these difficulties. Second, the ability to choose learning methods that are in accordance with the material and student needs, for example using experiments, case studies, or project-based approaches for scientific materials such as science. In addition, the mastery of prospective teachers with learning aids, such as educational technology or interactive media, is also an important part of PCK readiness. Another indicator is the ability of prospective teachers to connect teaching materials with the context of students' daily lives. This aims to enable students to understand the relevance of the material they learn to the real world. The readiness of PCK can also be seen from the reflective ability of prospective teachers to evaluate the effectiveness of their teaching strategies and make improvements based on student input or learning outcomes. Thus, prospective teachers

who have PCK readiness are able to teach material accurately, relevantly, and interestingly, while ensuring that students are actively involved in the learning process.

Content knowledge is now an uncertainty because information technology transfers big data excessively to everyone. Excessive material is sometimes not in accordance with the mental development of a student. Students have their own material packages that must be taught according to their age. This content knowledge should be the basic capital for students to be able to teach in schools. This content knowledge includes an understanding of the material, explaining what material will be taught at the beginning of the semester, and what material will be taught afterwards. If students are not ready to understand the material, then further learning will stop. For example, the material that will be taught in the initial class is basic material such as biodiversity and ecosystems, while the advanced material that must be taught is cells, reproductive systems, and genetics. The material should not be reversed from the way it is given to students because the material is a form of continuous learning. Content seems to be outdated and technology has changed.

The relationship between pedagogical knowledge and content knowledge will be explained in more detail on each indicator of pedagogical ability which includes 10 things. These indicators will be associated with the content of science material that will be taught to students. Each indicator of pedagogical ability has its own relationship with content knowledge. Pedagogical ability is determined by 10 indicators. Teachers must master these indicators to be able to declare themselves knowledgeable and capable of being professional in pedagogical skills. The following will be described 10 indicators of pedagogical ability according to the Indonesian Ministry of National Education (2007), including 1) mastery of student character. 2) understanding related to learning theories 3) being able to develop a curriculum. 4) carrying out development activities. 5) utilizing technology for learning media. 6) providing facilities to develop students' potential. 7) communicate effectively, empathetic and polite to students. 8) conduct assessments and evaluations of learning processes and outcomes. 9) utilizing the results of assessment and evaluation. 10) Carry out reflective actions in improving the quality of teaching and learning. The 10 indicators of pedagogical ability will be discussed with content knowledge in science material to be able to find out the unity of pedagogical knowledge (PK) and content knowledge or (CK).

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3.1. Mastery Of Student Character

Mastery of students' character is very important in pedagogical ability. A good teacher is a teacher who can understand the condition of his students. The condition of the student is what is meant by the character of the student. Teachers' pedagogic competence in Indonesia requires teachers to be able to understand the development of student psychology by looking at their characters. The pedagogical competence of teachers in the Philippines also states that teachers must be able to appreciate the personal growth of students. This means that a teacher must be able to understand the development of student psychology to be able to determine the right learning strategy. The character of students is directly proportional to the learning model used. Student characteristics are very important for educators to know, because this is very important to be used as a reference in formulating learning strategies. Learning strategies are prepared by teachers and implemented through learning methods to students so that learning goals can be achieved effectively and efficiently. The development of students' self-potential carried out by teachers can be done in several ways, namely by providing intensive guidance to students, providing assistance to underprivileged students, providing good examples, inviting students to jointly clean the school environment, carrying out congregational dhuha prayers every Friday morning, conducting tests for new students, holding extracurricular activities, and giving sanctions and awards to students. Then what is an obstacle for teachers in developing students' self-potential is students' innate attitudes, interests and motivations, teacher competence, school facilities and infrastructure, and the environment around students (Septianti, N., & Afiani, R, 2020).

The character of students combined with the right learning model will make it easier for teachers to convey learning materials. For example, if the teacher wants to deliver photosynthesis material on leaves to students with active characters, then the learning model chosen is based on practicum or discovery. The discovery-based learning model will make active students feel facilitated to do practicum in finding new materials related to photosynthesis.

3.2. Understanding Related Learning Theories

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Learning theory is a guideline for all teachers in carrying out learning. Learning theory contains the meaning of learning, the meaning of learning, and the types of learning methods from various experts. Teachers must understand the meaning of this learning theory starting from behavioristic, constructivistic, cognitivism, and humanistic theories. A teacher who understands learning theory will understand how to guide learning so that students can easily accept the material. Pedagogical learning in the Philippines requires professional teachers to understand the importance of mastery of knowledge, content, and its relevance within and throughout the curriculum (Philippine DepEd Order No. 42, 2017). Teachers in Indonesia are also required to master competencies related to understanding learning theories. Learning theory is the foundation of a learning process that leads to the formation of learning conditions. Therefore, the existence of learning theories will provide convenience for teachers in implementing the learning model that will be implemented and will help students in learning (Saefiana et al., 2020). Learning theory will provide an understanding to a teacher about a child's learning style. The right learning style used by a student will make it easier for him to understand the material. A student has a behavioristic learning style, so he will easily understand abstract material. The abstract material, for example, is virus material that will be understood if memorized repeatedly.

3.3. Curriculum Development

The curriculum is the main reference for a school in organizing learning. A good curriculum is a curriculum that is always developed every year. Curriculum development aims to adapt education to social changes as well as explore previously untouched knowledge (Harmita, D., & Aly, 2023). Curriculum development must be carried out by a teacher to be able to update the curriculum in accordance with technological developments and the development of the times. Teachers in the Philippines under the regulations of the Department of Education of the Republic of the Philippines must understand how to translate the content of the curriculum into learning activities that are relevant to students and based on the principles of effective teaching and learning. This is also in line with what teachers in Indonesia must do, teachers in Indonesia must understand the principles of curriculum development. Curriculum development is also related to determining learning objectives. Teachers in determining learning objectives in the curriculum must understand the teaching materials. The curriculum contains all the learning objectives achieved so that students can understand and accept all the material. The content of science material must be well

understood by a teacher so that the curriculum prepared is effective and efficient for students. Without knowledge of the content, a teacher cannot compile a curriculum properly.

3.4. Implementation of Development Activities

The development referred to here is the development of teachers' professional abilities. Although teachers have already given lectures when they want to earn a bachelor's degree, their competencies must always be honed to keep up with the demands of the ever-evolving world of education. Efforts that can be made to improve teacher professionalism are through the adoption of innovation or the development of creativity in the use of educational technology that utilizes the latest communication and information technology to develop teacher professionalism competencies (Zahara et al., 2024). In addition, development activities that must always be followed by teachers are the development of the ability to make learning media, workshops on making evaluation instruments, curriculum development workshops, learning model development workshops, and various types of learning support workshops.

3.5. Utilization of Technology for Learning Media

The use of technology in learning media can provide many benefits for the learning process. Technology is one of the tools that is often used as a learning medium apart from the practical side. Theuse of technology in learning is also included in the demands of the world of education. Theuse of technology is also a special attraction for students, because students tend to be more enthusiastic in learning. Learning media is a way to channel trust between teachers and students, trust here means subject matter in which there is a message that must be understood by students, therefore the selection of learning media is also very important so that the message is conveyed by students. Teachers can convey material optimally through learning media and students can understand the message conveyed by the teacher (Suminar, 2019). Here are some activities that teachers can do in utilizing technology as a learning medium such as online learning, the use of multimedia, the use of social media as a learning resource, e-books and online articles. Online learning includes the use of platforms such as Google Classroom, Zoom, or Microsoft Teams to

host online classes. Information technology can also be used as a medium to deliver assignments and exams online using an LMS (Learning Management System) platform such as the moodle application. The use of Multimedia can be used tocreate and display learning videos in explaining difficult concepts. Theuseof animationand simulation with multimedia can be used to clarify abstract or complex material. E-Books and onlinerticles can also be used by teachers as additional reference materials as well as directing students to online educational resources.

3.6. Student Potential Development Facilities

Facilities are one of the main means for children to want to learn. If the facilities are adequate, children will begin to be interested in learning. Learning is one way to find out what potential exists in students. Students at school do not all know their potential, so it is the facilities that will help them know their identity or talents. Students who already know their talents and potentials will hone them further with the facilities that have been provided at school. The minimum facilities in the school are physics laboratories, chemistry laboratories, biology laboratories, sports fields, wifi, computers, and social studies laboratories. These facilities must exist and be used by teachers to find student potential or develop student potential. Teachers must learn by utilizing various facilities in schools. For example, teachers must make practicum learning in the laboratory, teachers make learning media that ask students to access with computers. The development of students' self-potential carried out by other teachers is by providing intensive guidance to students, providing assistance to students who lack interest and motivation in learning, setting a good example, inviting students to jointly clean the school environment, carrying out spiritual refreshment activities every morning, holding repetitions for new students, holding extracurricular activities, and giving sanctions and reprimands to students (Amaliyah, A., & Rahmat, 2021).

3.7. Communicate effectively, empathetically and politely to students

A good teacher is a teacher who is always friendly and polite to his students. Teachers have 2 characters that must be mastered, namely strict discipline in class and friendly in communicating with students. Teachers can communicate effectively by actively listening to every word of

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students. Suppose the teacher pays full attention when students speak, and always uses clear and simple language. Teachers must use language that is easy for students to understand.

Teachers must also always try to show empathy so that effective communication with students can run smoothly. Teachers who are polite to students always try to give praise and support when students answer questions properly and correctly. In addition to the above, to demonstrate effective communication, teachers must be able to be open and honest, use positive body language, provide space for students to speak, be patient and tolerant. The above methods can be used to build a better relationship between teachers and students. Good communication between students and teachers can create a positive learning environment, and increase learning effectiveness. The teacher's ability to provide the right reward for the success of students makes students better understand the material being taught, in addition to the teacher's activities that communicate enthusiastically and earnestly in learning activities make students more motivated and easily understand the material (Putri, 2020).

~~1.8. **Penerapan dan Pemanfaatan Evaluasi Proses dan Hasil Pembelajaran**~~

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Evaluation of learning processes and outcomes is an important step to ensure the effectiveness of teaching and the achievement of educational goals. Teachers can evaluate learning in 3 ways, namely diagnostic evaluation, formative evaluation, and summative evaluation. Other evaluations can also be done by making a reflective journal at the end of each teaching session to evaluate what is already good and what needs to be improved. Evaluation can be done using an online learning platform that provides automatic evaluation features and at the same time to track student progress. Teachers can also ask students to work in groups and create collaborative projects that demonstrate their understanding and skills. Evaluation can also be done by self-evaluation, where students evaluate themselves and identify areas that need improvement. Students can also conduct peer assessments. Peer assessment to provide additional perspective on their performance. Evaluation aims to find out the level of student achievement in a learning process, as well as understand students about the extent to which they can provide assistance to student shortcomings, with the aim of placing students in more appropriate learning situations according to their needs. according to their ability level. Meanwhile, the function of evaluation is to help the

process, progress and development of student learning outcomes in a sustainable manner, as well as to be able to find out students' abilities and weaknesses in certain fields of study, as well as to provide information to parents/guardians of students regarding the determination of class promotion or the determination of student graduation (Idrus, 2019).

3.9. Reflective Actions in Improving the Quality of Teaching and Learning

Reflective action is a process in which teachers critically analyze their teaching practices to improve the quality of learning. Teachers can conduct flexible learning by taking daily notes after each teaching session, asking students to provide regular feedback through surveys, questionnaires, or open discussions. By implementing these measures, teachers can consistently improve the quality of learning they provide, as well as create a more effective and supportive learning environment for students. Through the reflective thinking process carried out by applying the four stages of a complete reflective thinking process, it can help teachers in becoming reflective individuals. The results of this reflection can help teachers to find solutions that can be applied to problems in the classroom. It is important for teachers to reflect, because being a reflective person is a real action for redeemed humans. By reflecting, people are aware of their mistakes, and continue to try to find solutions to their problems as concrete actions from themselves who want to change for the better (Manurung & Listiani, 2020).

Teachers must adapt to their learning activities and find the right learning strategies and technology to be used in the delivery of teaching materials (Denby and Holman, 2002). PCK is a framework that teachers need to have a deep understanding of the pedagogical components and structure of teaching materials. PCK is a complex form of integration of content knowledge (CK) and pedagogical ability (PK). PCK is an important framework that must be known by a teacher, because PCK will always be used in learning activities and related to students' interest in learning and understanding the material (Tondeur et al., 2017). Koehler and Mishra (2019) argue that PCK helps teachers understand and can use this form of knowledge in the teaching and learning process. Teachers need to know what and how they apply learning strategies or models in a unique context in their classrooms.

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The development of teachers' abilities towards PCK in ASEAN is influenced by national education policies which include government regulations and teacher competency activities in designing learning. The quality of learning will depend on learning activities, the way the material is delivered, and the way the teacher teaches. The challenge of this PCK can be seen from the suitability of learning strategies with teaching materials. A wise teacher must adapt the learning strategy to the characteristics of the material. However, for teachers who do not understand PCK, they will teach with the aim that the material is only delivered to students without looking at student activities in learning. Therefore, schools and organizers must have training courses or professional development programs for teachers and prospective teachers, especially professionals in the field of pedagogy and professionals in understanding teaching materials.

A good teacher is a teacher who is willing to develop learning strategies and adjust to the needs of students. Design thinking must be used for instruction-based classroom activities in preparing teachers in PCK. The state needs to set educational management goals by helping teachers know, understand and be able to use PCK in the teaching process (Blau, I. and Shamir-Inbal, 2017). Especially the teacher preparation program or pre-service teachers who are the younger generation in schools, who understand the development of new learning strategies and are enthusiastic about learning innovations in accordance with the demands of the 21st century. PCK's empirical studies of prospective science teachers show that all areas of knowledge show that they understand the integration of pedagogy, technology and bring different methods and ideas into the classroom learning environment. Teacher preparation programs need to pay attention to teacher competencies and embed PCK into the study program. While the nature of learners' learning is changing, teachers must adapt teaching strategies and they can utilize educational technology for effective teaching (Prachagool, V. and Nuangchalerm, 2019).

The Relationship of Pedagogical Content Knowledge (PCK) to Realize Sustainable Development Action

Pedagogical Content Knowledge (PCK) is an educational concept that emphasizes the ability of teachers to integrate content knowledge and pedagogy in a harmonious manner to create effective

learning (Siow Heng Loke et al., 2015; Zubaidah et al., 2023)). PCK has a central role in sustainable development action because it can help educators deliver educational materials related to sustainability in a way that is relevant, interesting, and meaningful for students. Teachers who have a strong PCK are able to bridge the gap between sustainability theory and real practice, so that students not only understand the concepts of sustainability, but are also motivated to take real actions in daily life. Based on the table 3, prospective students of Science teachers from the Philippines and Indonesia have a readiness that is very ready and quite ready more than 90%. This suggests that students who have PCK readiness have been considered able to bridge students to understand sustainability concepts and motivate them to take real action in their daily lives.

Education oriented towards sustainable development demands a multidisciplinary approach that combines social, environmental, and economic aspects (Araneo, 2024). Through PCK, teachers can design learning strategies that combine scientific knowledge, moral values, and practical skills. For example, in learning about climate change, a teacher with a good PCK can integrate scientific data on carbon emissions with discussions of environmental ethics and action-based projects, such as planting trees or reducing the use of plastics. Thus, PCK allows learning not only to be a means of knowledge transfer, but also a process of character formation that supports sustainable development.

PCK is also relevant in building students' critical awareness of global and local issues related to sustainable development. Teachers can use critical pedagogical approaches to help students understand the root causes of sustainability issues, such as social inequality, exploitation of natural resources, and pollution. Through this understanding, students are encouraged to think critically, find creative solutions, and take responsible collective action. PCK allows teachers to facilitate productive and collaborative dialogue in the classroom so that students feel they have an important role to play in sustainable development efforts (Forsler et al., 2024). In addition, PCK supports the development of 21st century skills, such as problem-solving, collaboration, and digital literacy, which are critical in realizing sustainable development (Shafie et al., 2019). In the learning process, teachers can utilize innovative technologies and methods to provide an authentic learning

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experience (Ramaila & Molwele, 2022). These innovative learning methods, for example, such as project-based learning and problem-based learning, can provide students with real learning experiences to provide meaningful learning. This approach not only increases student engagement, but also helps them understand the complexity of sustainability issues and the importance of cross-sectoral cooperation to address them.

PCK plays a key role in supporting education as a tool of social transformation for sustainable development (Forsler et al., 2024). With a strong PCK, teachers can create relevant, inspiring, and action-based learning, ultimately helping to shape an environmentally conscious, socially responsible, and empowered generation in the face of global challenges. In the long term, investing in the development of PCK for educators is a strategic step to strengthen the education system and achieve a vision of a more equitable, inclusive and sustainable world.

The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies. With a strong understanding of PCK, prospective teachers can design contextual, interdisciplinary, and meaningful learning, thereby equipping students with the awareness and skills to contribute to sustainable development. Therefore, improving the PCK competency of prospective science teachers must be a priority in teacher education to create a generation that is able to face global challenges and realize sustainable development goals.

CONCLUSION

This study reflects that 44.9% of Indonesian students and 58.5% of Filipino students who will work as prospective science teachers have pedagogical content knowledge (PCK) readiness. As many as 41.5% of Indonesian students and 49.3% of Filipino students are in the category of being quite ready to know and master pedagogical skills and the content of science materials. With a strong understanding of PCK, prospective teachers can design contextual, interdisciplinary, and

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meaningful learning, thereby equipping students with the awareness and skills to contribute to sustainable development. Improving the PCK competence of prospective science teachers must be a priority in teacher education to create a generation that is able to face global challenges and realize sustainable development goals.

The content of science material is always related to pedagogical skills, in this study the content of the material is always closely related to the 10 indicators of pedagogical ability which include 1) mastery of student character 2) understanding related to learning theories 3) being able to compile a curriculum 4) carrying out development activities 5) utilizing technology for learning media 6) Providing facilities to develop student potential 7) Communicating effectively, empathy and courtesy to students 8) Conducting assessments and evaluations of the learning process and results 9) Utilizing assessments and evaluation results 10) Carrying out reflective actions in improving the quality of teaching and learning.

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The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies.

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Pedagogical Content Knowledge (PCK) of Sains Prospective Teachers in ASEAN to Realize Sustainable Development Action (SDGs)

Double-blind review

Double-blind review

*Coresponding author : Double-blind review

Informasi artikel

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Dipublikasi:

Kata kunci:
ASEAN
PCK
Readines
Student
Sains Teacher
SDGs

ABSTRAK

Calon guru IPA sangat penting untuk memiliki penguasaan terkait pengetahuan pedagogis (PK) dan pengetahuan material (CK) terkait materi IPA atau yang biasa kita kenal dengan Pengetahuan Konten Pedagogis (PCK) sebelum terjun ke dunia kerja. PCK merupakan pengetahuan wajib yang harus dikuasai oleh calon guru. Penelitian ini bertujuan untuk menganalisis kesiapan PCK bagi calon guru IPA di Indonesia dan Filipina. Penelitian ini akan menjelaskan terkait CK dan PK yang harus dikuasai oleh guru yang akan mengajar di kawasan ASEAN. Data ini dikumpulkan dengan melakukan survei terhadap 110 calon guru yang sedang melakukan praktik lapangan di sekolah-sekolah di Filipina dan Indonesia. Data juga diperkuat dengan melakukan wawancara dengan 6 calon guru di Indonesia dan 6 calon guru di Filipina. Data yang dikumpulkan terkait dengan apa yang mereka pahami dan siapkan dari segi pedagogi dan materi sains. Hasil penelitian ini menunjukkan bahwa kemampuan PCK mereka rata-rata pada level ready. Temuan penelitian ini menunjukkan bahwa guru harus meningkatkan pengetahuannya terkait pengetahuan muatan pedagogis (PCK) karena jumlah siswa sebagai calon guru IPA yang berada dalam kategori siap masih relatif rendah, yakni 44,9 -58,5%. Peningkatan PK dapat dilakukan dengan memberikan tambahan kursus pendidikan dan pelatihan pedagogis untuk meningkatkan keterampilan pedagogis. Peningkatan CK dapat dilakukan dengan menambahkan mata kuliah khusus untuk materi IPA di sekolah sebelum mereka berlatih mengajar ke sekolah. Kesiapan calon guru IPA dalam memahami Pedagogical Content Knowledge (PCK) berperan penting dalam mendukung aksi pembangunan berkelanjutan. PCK tidak hanya mencakup kemampuan calon guru untuk mengintegrasikan pengetahuan bahan ajar dan strategi pedagogis, tetapi juga kemampuan mereka dalam menyampaikan konsep ilmiah yang relevan dengan isu keberlanjutan, seperti perubahan iklim, konservasi sumber daya alam, dan teknologi ramah lingkungan.

Keywords:
ASEAN
PCK
Readines
Student
Sains Teacher
SDGs

ABSTRACT

Prospective science teachers are very important to have mastery related to pedagogical knowledge (PK) and material knowledge (CK) related to Science or what we commonly know as Pedagogical Content Knowledge (PCK) before entering the world of work. PCK is mandatory knowledge that must be mastered by prospective teachers. This study aims to analyze the readiness of PCK for prospective science teachers in Indonesia and the Philippines. This research will explain related to CK and PK that must be mastered by teachers who will teach in the ASEAN region.

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This data was carried out by conducting a survey of 110 prospective teachers who are conducting field practice in schools in the Philippines and Indonesia. Data was also collected by conducting interviews with 6 prospective teachers in Indonesia and 6 prospective teachers in the Philippines. The data collected is related to what they understand and prepare in terms of pedagogy and science materials. The results of this study showed that their PCK ability was average at the ready level. The findings of this study show that teachers must improve their knowledge related to pedagogical content knowledge (PCK) because the number of students as prospective Science teachers who are in the ready category is still relatively low, namely 44,9 - 58,5%. Improving PK can be done by providing additional pedagogical education and training courses to improve pedagogical skills. Improving CK can be done by adding special courses for Science material in schools before they practice teaching to schools. The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies.

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INTRODUCTION

Education is a field of work that will be engaged in by prospective science teachers. Education includes teacher teaching activities and student learning activities. The new era of education in the current school curriculum is centered on student center learning. Students are not required to have good learning results to get first place, but students are required to master a good learning process. In order for students to obtain a good learning process, a teacher must understand how to teach and how to make students understand the material by doing activities or practicums. The material received by students from year to year will change along with the development of the times and technology, so that in this new era of education students are not required to only master the material but must be able to do activities to find a material.

The dynamic development of science in accordance with the development of the times makes teachers always have to be creative in making learning activities. Learning activities must be adjusted to the demands of the times. To answer this, it is very important for teachers to master classroom management and the development of ever-changing materials that will be given to

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students. This is in accordance with the theory that states that the challenge to prepare for future life is by learning 21st century skills where children will be faced with uncertain situations in the future (Hong et al., 2019). Uncertainty in the future is related to the material that students will receive that is always changing and evolving. Changes in the material received by students must be in line with changes in the way a teacher teaches. If the change in material is taught in the way of teaching in the past, for example lectures, then students will not understand and learning does not make students actively search for the material themselves.

Pedagogical Content Knowledge (PCK) according to Shulman (1987) is to characterize teachers' knowledge to instructional explicitly with integrated pedagogy and content as well. PCK contains two main components, namely Content Knowledge (CK) and Pedagogical Knowledge (PK). First, CK describes the knowledge of prospective teachers regarding the subject matter of the material to be taught. Knowledge of this content is one of the most important components as a requirement to become a teacher (Shulman, 1986). Second, PK describes the knowledge of prospective teachers about mastery of practices, processes, strategies, procedures, and methods in the teaching and learning process (Shulman, 1986).

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PCK merupakan ilmu penting yang harus dikuasai oleh calon guru sebagai dasar untuk membantu dan making it easier for students to understand difficult concepts. PCK can also improve knowledge and skills including critical thinking, creativity, communication and collaboration skills (Cetin-Berber, D. & Erdem, A, 2015). Teachers who master PCK are believed to be able to create a fun learning atmosphere and make it easier for students to understand the material.

PCK is an idea where the delivery of material must be adjusted to the teacher's teaching method which is not monotonous and always changes every meeting. For example, the first day with the docovery learning model, the second day with the project-based learning model, and the third day with the cooperative learning model. Changes in teaching methods will make students interested in starting learning activities. Students will always want to know what new learning activities the teacher uses in each of their meetings. If the motivation of students in participating in learning activities has appeared, the learning material will be very easy for students to accept. PCK plays a very effective role in teacher development to achieve effective learning activities.

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Pedagogical knowledge includes mastery of student characteristics, mastery of learning theories and principles of educational learning, curriculum development, educational learning activities, development of student potential, how to communicate, and mastery of student assessment and evaluation. Pedagogic competence includes 10 standards, namely 1) mastery of students' character. 2) understanding related to learning theories 3) being able to develop a curriculum. 4) carrying out development activities. 5) Utilizing technology for learning media. 6) providing facilities for the development of students' potential. 7) communicate effectively, empathetic and polite to students. 8) conduct assessments and evaluations of learning processes and outcomes. 9) utilizing the results of assessment and evaluation. 10) Carrying out reflective actions in improving the quality of teaching and learning (Kementerian Pendidikan Nasional Indonesia, 2007).

Philippines is a country that prioritizes teachers who have good pedagogical skills. Government regulations in the Philippines are also clear that there are 7 main domains for a teacher to be effective in organizing learning according to the demands of education in the 21st century. Qualified teachers in the Philippines need to possess the following characteristics: recognize the importance of mastery of content knowledge and its relevance within and across curriculum areas; provide a safe, secure, fair and supportive learning environment to increase student responsibility and achievement; building a learning environment that is responsive to the diversity of students; interact with national and local curriculum requirements; implementing various assessment tools and strategies in monitoring, evaluating, documenting and reporting on students' needs, progress and achievements; establishing school-community partnerships that aim to enrich the learning environment, as well as community involvement in the educational process; Valuing personal growth and professional development and showing high personal respect for their profession by maintaining qualities that uphold the dignity of teaching such as caring, respectful and integrity (Philipines DepEd Order Number. 42, s, 2017).

A good teacher is a teacher who can involve students in all learning activities in the classroom. Teachers must understand the 10 pedagogic competency standards so that learning activities are more meaningful. PCK is knowledge about the pedagogical relationship with the learning materials that will be given to students. PCK is a basic ability for teacher ability development. The development of teachers in Indonesia is supported by teacher professional

education (PPG) which must be pursued by education graduates. Teachers are expected to develop into a profession that can support 21st century skills and the development of technological advances by creating quality students. The concept of teacher education focuses on technology education that is integrated in PCK or pedagogical content knowledge (Shulman, 1986). Learning practices use PCK to acquire the knowledge and skills students need that are relevant to the content, culture, context and psychological role (Denby, D, and Holman, J , 2002). PCK is a science that really helps teachers to create a common ground between the material to be delivered at school, the content of learning, and pedagogical competence. Nuangchalerm (2020) shows that PCK can help teachers learn to be good at teaching and better understand pedagogical skills. Teachers who already know the content of the material must think about what learning model is suitable for use in learning activities so that all students can be active.

Science is a material that really needs a variety of learning models to make students understand the material. Prospective science teachers must be able to understand pedagogical skills and use these skills to teach a wide variety of science materials. The readiness of prospective teachers in terms of PCK will be very important to know to be able to find problems related to this. This research will be very important to produce conclusions related to the condition of prospective science teachers in Indonesia and the Philippines to find out the PCK. According to Shulman (1987), teacher preparation programs must combine pedagogical knowledge and content knowledge to teach and learn appropriately. PCK is the ability to combine knowledge of a particular discipline with science teaching. This makes teachers really understand the content and turn it into appropriate teaching (Shulman, 1986). Students who are interested in learning activities will also begin to be interested in learning the material. The combination of fun learning activities and the material taught will be easily accepted by students if their hearts are happy.

Heibert et al (2007) proposed a teacher preparation framework to help develop teacher competencies in setting learning objectives, evaluating student performance, hypothesizing the relationship between learning materials and self-reflection teaching. Social changes and learning environments are pushing the trend of PCK to a higher level of use (Nuangchalerm, 2020). PCK is a science that must be mastered by prospective teachers to develop skills and professionalism in teaching. The combination of 2 elements, namely pedagogy and material content, is very basic so that teachers can work professionally. This study aims to analyze PCK in ASEAN education and

connect PCK with prospective science teachers. The results of this research will be used as input for the Teacher Professional Education program in Indonesia and Philippines. The results of this research are also expected to be an input for universities to provide further knowledge related to PCK by combining it in courses.

Teachers in the future need to master a good understanding of how pedagogical knowledge and content can be effective in the learning process in the classroom. To answer this need, Koehler and Mishra (2019) introduced a conceptual framework called Pedagogical Content Knowledge (PCK) which was obtained from the addition of technology to Pedagogical Content Knowledge (PCK) which is a conceptual framework built by Shulman (1986). According to Karaca (2015), the development of the PCK model provides an overview for prospective teachers and academics that the model can help improve the ability to integrate technology in the learning process in the classroom to find out the latest material content. PCK as a relationship between pedagogical knowledge and content that is the basis of good teaching.

The content of the material that is interacted with good pedagogical skills will be able to help solve the problems faced by students in carrying out effective, innovative and fun learning. The integration of pedagogical skills in the delivery of teaching materials requires a structured and creative design in its application, in addition to that, the right approach is also needed in the learning implementation plan with the context of the material to be delivered. This PCK knowledge will be very meaningful for prospective teachers to form a teaching activity when they have entered the world of work.

The Sustainable Development Goals (SDGs) are a global agenda launched by the United Nations (UN) to achieve inclusive, sustainable, and environmentally sound development (Kleespies & Dierkes, 2022; Whittingham et al., 2023). The SDGs in goal no. 4 emphasize the importance of providing quality education that reaches all levels of society. SDGs-oriented education aims to equip students with knowledge, skills, values, and attitudes that support the achievement of sustainable development. This includes awareness of global issues, such as climate change, gender equality, social justice, and environmental conservation.

The implementation of the SDGs in learning is essential to ensure that future generations not only become academically competent individuals, but also socially and ecologically responsible.

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Therefore, teachers have a central role in integrating SDGs values into the learning process. Teachers are expected to be able to design learning tools that are relevant to SDGs issues, so that students can understand and apply these concepts in real life. However, the success of the integration of SDGs in learning is highly dependent on the readiness of teachers' pedagogical content knowledge (PCK). PCK is a framework that includes knowledge of the content to be taught, effective pedagogical strategies, and an understanding of students' needs and characteristics. In the context of implementing the SDGs, teachers' PCK must include the ability to identify learning topics relevant to the SDGs, develop teaching methods that motivate students to think critically and act solutive on global issues, and develop learning evaluations that can measure students' understanding of SDGs issues.

Teachers' PCK readiness is a crucial aspect because not all teachers have adequate competence and experience in integrating the SDGs into the SDGs learning tools. For this reason, training and professional development for teachers is a necessary step. This training must include an in-depth understanding of the SDGs, innovative teaching strategies, and assessment techniques that support SDGs-based learning. Thus, teachers can be more confident and skilled in designing learning that not only prioritizes academic achievement, but also shapes the character of students with a global perspective.

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RESEARCH METHOD

This study will use the research design of the explanatory sequential mixed method. The design of the sequential mixed method of explanation (also called the two-phase model; J. W. Creswell & Clark (2017) consists of first quantitative data collection and then qualitative data collection to help explain or elaborate the quantitative results. The reason for this approach is that the quantitative data and results provide an overview of the research problem; Further analysis, particularly through qualitative data collection, is necessary to refine, expand, or explain the general quantitative picture (Creswell, J., & Guetterman, 2018). The respondents of this study are students who will become prospective science teachers in 2 countries. The respondents consisted of 41 Indonesian students and 69 Philippines citizens.

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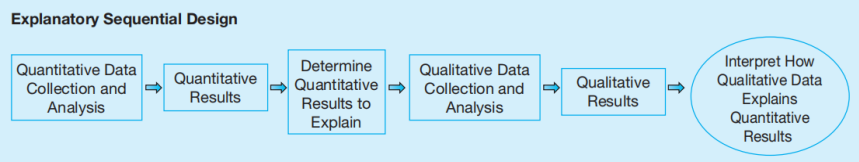

Figure 1. Explanatory Sequential Design

The analysis will be carried out in such a way that a quantitative investigation will be carried out first and then a qualitative investigation will follow. Quantitative inquiries will be used to collect information about the readiness of prospective teachers in terms of technological readiness, pedagogy, and content knowledge. Qualitative investigations will continue after participants with the least, most, and moderate readiness are identified.

RESULT

This research was conducted in two countries. These countries are Indonesia and the Philippines. The results of the research that we present also involve data from 2 countries. The results of this study will describe the condition of knowledge pedagogy readiness and knowledge content in Indonesia and the Philippines.

Table 1. Level of PK (Pedagogical Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	42	60.9	35	85.4
Moderately Ready	26	37.7	6	14.6
Not Ready	1	1.4	0	0
N=	69	100.0	41	100.0

Table 1 shows that from the Philippines there are 42 students who are ready to master pedagogical skills and apply pedagogical knowledge to the classroom, while in Indonesia there are 35 students who are in the ready category. Students who are quite ready to understand pedagogy from the Philippines are 26 people while Indonesia is 6 people. This fairly ready category shows that students have not mastered too many indicators that must be achieved in Pedagogy. The pedagogical knowledge assessed in this study is to see how to assess student performance in the

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classroom, how to teach, my teaching style for diverse students, how teachers use various teaching approaches, how to overcome student misunderstandings, how to manage the classroom, and how to adapt the learning approach to the student's condition.

Table 1 above explains about students who belong to the group that are not prepared for mastering pedagogical knowledge. There is 1 student from the Philippines who is still not ready to master pedagogical knowledge while from Indonesia there are no students who are in the category of not ready. The lack of pedagogical science means that students do not know much about how to teach, how to assess, how to make school administration. Overall, the results of this study reflect that 85.4% of Indonesian students and 60.9% of Filipino students who will work as prospective science teachers have readiness in pedagogical skills. Meanwhile, 14.6% of Indonesian students and 37.7% of Filipino students are in the fairly ready category. The category of students from the Philippines who do not have the readiness to master pedagogical knowledge is 1.4%.

Pedagogical Knowledge (PK) is the knowledge possessed by a teacher about effective learning principles, methods, and strategies. The indicators of Pedagogical Knowledge include several main aspects that include the ability to understand learning theories, design learning, manage classrooms, conduct assessments, and utilize educational technology. Teachers who have a good PK are able to understand how students learn, choose methods that suit their learning needs, and create a classroom environment that is conducive to learning. One of the main indicators is the understanding of prospective teachers about the student learning process. It includes knowledge of cognitive development theories, learning styles, motivations, and diverse learning needs. In addition, the ability to design learning is also an important indicator. Prospective teachers must be able to make a Learning Implementation Plan that is in accordance with the curriculum, choose relevant learning methods, and determine measurable learning goals.

Table 2. Level of CK (Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	37	53.6	21	51.2
Moderately Ready	30	43.5	20	48.8
Not Ready	2	2.9	0	0
N=	69	100.0	41	100.0

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Table 2 shows that from the Philippines there are 37 students who are ready to understand the content of science material and implement science material that will be taught in class, while in Indonesia there are 21 students who are in the ready category. Students who are quite ready to understand the content of science material come from the Philippines totaling 30 people while Indonesia totals 20 people. This category of quite ready shows that students have not mastered the indicators that must be achieved in science knowledge material. The knowledge of the content of science material assessed in this study is that students have sufficient knowledge of physics, chemistry, biology. The second indicator is that students can integrate SETS (Science, Environment, Technology, and Society) in classroom learning. The third indicator is that students can match science material with the learning approach they want to use. The fourth indicator is that students can apply contextual learning, namely presenting science in real life. The fifth indicator is that students can apply their knowledge in the fields of Physics, Chemistry, and Biology and slice it into classroom learning. The eighth indicator is that students have extensive knowledge that is currently taught, namely biophysics, biochemistry, environmental balance, plants, animals, global warming.

Table 2 above also explains about students who belong to the unprepared group. There were 2 students from the Philippines while from Indonesia there were no students who were included in the unprepared category. The lack of pedagogy means that students do not know much about what science materials must be taught to students at school. In addition, they also lack understanding of the latest and current material that must be mastered if they want to become science teachers. Overall, the results of this study reflect that 53.6% of Indonesian students and 51.2% of Philippines students who will work as prospective science teachers have the readiness of science material content. Meanwhile, 48.8% of Indonesian students and 43.5% of Philippines students are in the category of being quite ready to know the content of science material. The category of students from the Philippines who are not ready is 2.9%.

Content knowledge (CK) includes an in-depth understanding of basic concepts in science, the ability to explain scientific phenomena, and the skill of integrating various branches of science such as physics, chemistry, biology, and earth science. CK is very important to ensure that

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prospective teachers are able to deliver material correctly, accurately, and relevantly. One of the main indicators of CK is mastery of basic concepts in science. Prospective teachers must understand the main principles in science, such as the laws of physics, chemical cycles, the structure and function of living things, and geological processes. This knowledge must be holistic, which means that prospective teachers are able to see the connections between branches of science to provide students with a complete picture of the world of science. Another indicator of a prospective teacher mastering content knowledge is that the teacher can explain and model scientific phenomena clearly and logically. Prospective science teachers must be able to use easy-to-understand language to explain abstract concepts to students. For example, explaining the concept of gravitational force or photosynthesis with concrete examples that are relevant to daily life. This ability also includes the use of visual aids or practicum to clarify explanations.

The readiness of content knowledge can also be assessed from the ability of prospective teachers to relate science knowledge to the context of real life and global issues. For example, prospective teachers must be able to relate science concepts to environmental issues, such as climate change, pollution, or the energy crisis. This indicator shows that prospective teachers not only understand the theory, but also its relevance to student life and the challenges of the modern world. CK readiness indicators also include reflective abilities and knowledge updates. Science is a field that continues to develop, so prospective teachers must have a commitment to continue learning, keep up with the development of science, and update teaching materials according to new findings. Based on the above, the readiness of prospective science teachers is not only measured by the extent to which they master the material, but also from their ability to teach the material in a relevant, interesting, and contextual way.

Table 3. Level of PCK (Pedagogical Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	31	44.9	24	58.5
Moderately Ready	34	49.3	17	41.5
Not Ready	4	5.8	0	0
N=	69	100.0	41	100.0

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PCK knowledge or Pedagogical Content Knowledge contains 2 major elements, namely pedagogical skills and knowledge of teaching materials. Table 3 above shows that from the Philippines there are 31 students and from Indonesia there are 24 students who are categorized as ready to know pedagogical skills and the implementation of pedagogical science into science materials that will be taught to students. Students who are quite ready to understand PCK from the Philippines are 34 people while Indonesia is 17 people. This category of sufficient readiness indicates that students have not mastered the indicators that must be achieved in the PCK assessment. The things assessed in this study include how students choose an effective teaching approach to guide students' thinking and learning on science materials, how to choose different learning models to teach various topics on science materials, and how to choose different learning methods to teach various topics in science materials. science material. Table 3 above also explains about students who belong to the unprepared group. There are 4 students from the Philippines while from Indonesia there are no students who are included in the category of not ready. Not ready in terms of PCK means that students do not know much about how to connect the learning approach with the teaching materials that will be delivered to students. Overall, the results of this study reflect that 44.9% of Indonesian students and 58.5% of Filipino students who will work as prospective science teachers have pedagogical readiness and science material content. Meanwhile, 41.5% of Indonesian students and 49.3% of Filipino students are included in the category of being quite ready to know pedagogical skills and the content of science materials. The category of students from the Philippines who are not ready is 5.8%.

The data above shows that practicum activities in learning have not been carried out perfectly by prospective science teachers in two countries. It can be seen that only 44.9% of prospective science teachers in the Philippines and 58.5% of science teachers in Indonesia are ready to understand Pedagogy and Material Material. Students who are ready are those who are worthy of teaching in the school. Other students who are not ready should be guided first and given training until they are ready and master the PCK to be able to enter school. Practice and learning materials seem to be less seen as an absolute requirement for students to be ready to teach and become prospective teachers in schools.

DISCUSSION

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Pedagogical Knowledge (PK) is the knowledge possessed by a teacher about effective learning principles, methods, and strategies. The indicators of Pedagogical Knowledge include several main aspects that include the ability to understand learning theories, design learning, manage classrooms, conduct assessments, and utilize educational technology. Teachers who have a good PK are able to understand how students learn, choose methods that suit their learning needs, and create a classroom environment that is conducive to learning. One of the main indicators is the understanding of prospective teachers about the student learning process. It includes knowledge of cognitive development theories, learning styles, motivations, and diverse learning needs. In addition, the ability to design learning is also an important indicator. Prospective teachers must be able to make a Learning Implementation Plan that is in accordance with the curriculum, choose relevant learning methods, and determine measurable learning goals.

Content knowledge (CK) includes an in-depth understanding of basic concepts in science, the ability to explain scientific phenomena, and the skill of integrating various branches of science such as physics, chemistry, biology, and earth science. CK is very important to ensure that prospective teachers are able to deliver material correctly, accurately, and relevantly. One of the main indicators of CK is mastery of basic concepts in science. Prospective teachers must understand the main principles in science, such as the laws of physics, chemical cycles, the structure and function of living things, and geological processes. This knowledge must be holistic, which means that prospective teachers are able to see the connections between branches of science to provide students with a complete picture of the world of science. Another indicator of a prospective teacher mastering content knowledge is that the teacher can explain and model scientific phenomena clearly and logically. Prospective science teachers must be able to use easy-to-understand language to explain abstract concepts to students. For example, explaining the concept of gravitational force or photosynthesis with concrete examples that are relevant to daily life. This ability also includes the use of visual aids or practicum to clarify explanations.

The readiness of content knowledge can also be assessed from the ability of prospective teachers to relate science knowledge to the context of real life and global issues. For example, prospective teachers must be able to relate science concepts to environmental issues, such as climate change, pollution, or the energy crisis. This indicator shows that prospective teachers not only understand the theory, but also its relevance to student life and the challenges of the modern

world. CK readiness indicators also include reflective abilities and knowledge updates. Science is a field that continues to develop, so prospective teachers must have a commitment to continue learning, keep up with the development of science, and update teaching materials according to new findings. Based on the above, the readiness of prospective science teachers is not only measured by the extent to which they master the material, but also from their ability to teach the material in a relevant, interesting, and contextual way.

Understanding pedagogy or PK is a requirement so that students can choose the right learning strategy to teach the material. Understanding of teaching materials or CK is also a basic requirement so that students are ready to teach various materials that will be given at school according to their level. If PK and CK have not been mastered, what happens is that prospective teachers will always focus on the content and learning materials only and lack pedagogical strategies so that learning becomes boring because there are few student learning activities. Pedagogical Content Knowledge (PCK) is a combination of mastery of material (content knowledge) and the ability to teach it (pedagogical knowledge) effectively. PCK indicators include the ability of prospective teachers to understand the concept of teaching materials in depth, know the best way to deliver the material to students, and recognize the learning challenges faced by students. PCK integrates knowledge about "what is taught" and "how to teach" to make learning more effective and meaningful. The readiness of Pedagogical Content Knowledge of prospective teachers can be reviewed from several main indicators. First, the ability to identify important concepts in teaching materials that are often misconceptions for students. Prospective teachers must understand learning difficulties that may arise and be able to design learning strategies that can overcome these difficulties. Second, the ability to choose learning methods that are in accordance with the material and student needs, for example using experiments, case studies, or project-based approaches for scientific materials such as science. In addition, the mastery of prospective teachers with learning aids, such as educational technology or interactive media, is also an important part of PCK readiness. Another indicator is the ability of prospective teachers to connect teaching materials with the context of students' daily lives. This aims to enable students to understand the relevance of the material they learn to the real world. The readiness of PCK can also be seen from the reflective ability of prospective teachers to evaluate the effectiveness of their teaching strategies and make improvements based on student input or learning outcomes. Thus, prospective teachers

who have PCK readiness are able to teach material accurately, relevantly, and interestingly, while ensuring that students are actively involved in the learning process.

Content knowledge is now an uncertainty because information technology transfers big data excessively to everyone. Excessive material is sometimes not in accordance with the mental development of a student. Students have their own material packages that must be taught according to their age. This content knowledge should be the basic capital for students to be able to teach in schools. This content knowledge includes an understanding of the material, explaining what material will be taught at the beginning of the semester, and what material will be taught afterwards. If students are not ready to understand the material, then further learning will stop. For example, the material that will be taught in the initial class is basic material such as biodiversity and ecosystems, while the advanced material that must be taught is cells, reproductive systems, and genetics. The material should not be reversed from the way it is given to students because the material is a form of continuous learning. Content seems to be outdated and technology has changed.

The relationship between pedagogical knowledge and content knowledge will be explained in more detail on each indicator of pedagogical ability which includes 10 things. These indicators will be associated with the content of science material that will be taught to students. Each indicator of pedagogical ability has its own relationship with content knowledge. Pedagogical ability is determined by 10 indicators. Teachers must master these indicators to be able to declare themselves knowledgeable and capable of being professional in pedagogical skills. The following will be described 10 indicators of pedagogical ability according to the Indonesian Ministry of National Education (2007), including 1) mastery of student character. 2) understanding related to learning theories 3) being able to develop a curriculum. 4) carrying out development activities. 5) utilizing technology for learning media. 6) providing facilities to develop students' potential. 7) communicate effectively, empathetic and polite to students. 8) conduct assessments and evaluations of learning processes and outcomes. 9) utilizing the results of assessment and evaluation. 10) Carry out reflective actions in improving the quality of teaching and learning. The 10 indicators of pedagogical ability will be discussed with content knowledge in science material to be able to find out the unity of pedagogical knowledge (PK) and content knowledge or (CK).

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3.1. Mastery Of Student Character

Mastery of students' character is very important in pedagogical ability. A good teacher is a teacher who can understand the condition of his students. The condition of the student is what is meant by the character of the student. Teachers' pedagogic competence in Indonesia requires teachers to be able to understand the development of student psychology by looking at their characters. The pedagogical competence of teachers in the Philippines also states that teachers must be able to appreciate the personal growth of students. This means that a teacher must be able to understand the development of student psychology to be able to determine the right learning strategy. The character of students is directly proportional to the learning model used. Student characteristics are very important for educators to know, because this is very important to be used as a reference in formulating learning strategies. Learning strategies are prepared by teachers and implemented through learning methods to students so that learning goals can be achieved effectively and efficiently. The development of students' self-potential carried out by teachers can be done in several ways, namely by providing intensive guidance to students, providing assistance to underprivileged students, providing good examples, inviting students to jointly clean the school environment, carrying out congregational dhuha prayers every Friday morning, conducting tests for new students, holding extracurricular activities, and giving sanctions and awards to students. Then what is an obstacle for teachers in developing students' self-potential is students' innate attitudes, interests and motivations, teacher competence, school facilities and infrastructure, and the environment around students (Septianti, N., & Afiani, R, 2020).

The character of students combined with the right learning model will make it easier for teachers to convey learning materials. For example, if the teacher wants to deliver photosynthesis material on leaves to students with active characters, then the learning model chosen is based on practicum or discovery. The discovery-based learning model will make active students feel facilitated to do practicum in finding new materials related to photosynthesis.

3.2. Understanding Related Learning Theories

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Learning theory is a guideline for all teachers in carrying out learning. Learning theory contains the meaning of learning, the meaning of learning, and the types of learning methods from various experts. Teachers must understand the meaning of this learning theory starting from behavioristic, constructivistic, cognitivism, and humanistic theories. A teacher who understands learning theory will understand how to guide learning so that students can easily accept the material. Pedagogical learning in the Philippines requires professional teachers to understand the importance of mastery of knowledge, content, and its relevance within and throughout the curriculum (Philippine DepEd Order No. 42, 2017). Teachers in Indonesia are also required to master competencies related to understanding learning theories. Learning theory is the foundation of a learning process that leads to the formation of learning conditions. Therefore, the existence of learning theories will provide convenience for teachers in implementing the learning model that will be implemented and will help students in learning (Saefiana et al., 2020). Learning theory will provide an understanding to a teacher about a child's learning style. The right learning style used by a student will make it easier for him to understand the material. A student has a behavioristic learning style, so he will easily understand abstract material. The abstract material, for example, is virus material that will be understood if memorized repeatedly.

3.3. Curriculum Development

The curriculum is the main reference for a school in organizing learning. A good curriculum is a curriculum that is always developed every year. Curriculum development aims to adapt education to social changes as well as explore previously untouched knowledge (Harmita, D., & Aly, 2023). Curriculum development must be carried out by a teacher to be able to update the curriculum in accordance with technological developments and the development of the times. Teachers in the Philippines under the regulations of the Department of Education of the Republic of the Philippines must understand how to translate the content of the curriculum into learning activities that are relevant to students and based on the principles of effective teaching and learning. This is also in line with what teachers in Indonesia must do, teachers in Indonesia must understand the principles of curriculum development. Curriculum development is also related to determining learning objectives. Teachers in determining learning objectives in the curriculum must understand the teaching materials. The curriculum contains all the learning objectives achieved so that students can understand and accept all the material. The content of science material must be well

understood by a teacher so that the curriculum prepared is effective and efficient for students. Without knowledge of the content, a teacher cannot compile a curriculum properly.

3.4. Implementation of Development Activities

The development referred to here is the development of teachers' professional abilities. Although teachers have already given lectures when they want to earn a bachelor's degree, their competencies must always be honed to keep up with the demands of the ever-evolving world of education. Efforts that can be made to improve teacher professionalism are through the adoption of innovation or the development of creativity in the use of educational technology that utilizes the latest communication and information technology to develop teacher professionalism competencies (Zahara et al., 2024). In addition, development activities that must always be followed by teachers are the development of the ability to make learning media, workshops on making evaluation instruments, curriculum development workshops, learning model development workshops, and various types of learning support workshops.

3.5. Utilization of Technology for Learning Media

The use of technology in learning media can provide many benefits for the learning process. Technology is one of the tools that is often used as a learning medium apart from the practical side. Theuse of technology in learning is also included in the demands of the world of education. Theuse of technology is also a special attraction for students, because students tend to be more enthusiastic in learning. Learning media is a way to channel trust between teachers and students, trust here means subject matter in which there is a message that must be understood by students, therefore the selection of learning media is also very important so that the message is conveyed by students. Teachers can convey material optimally through learning media and students can understand the message conveyed by the teacher (Suminar, 2019). Here are some activities that teachers can do in utilizing technology as a learning medium such as online learning, the use of multimedia, the use of social media as a learning resource, e-books and online articles. Online learning includes the use of platforms such as Google Classroom, Zoom, or Microsoft Teams to

host online classes. Information technology can also be used as a medium to deliver assignments and exams online using an LMS (Learning Management System) platform such as the moodle application. The use of Multimedia can be used tocreate and display learning videos in explaining difficult concepts. Theuseof animationand simulation with multimedia can be used to clarify abstract or complex material. E-Books and onlinerticles can also be used by teachers as additional reference materials as well as directing students to online educational resources.

3.6. Student Potential Development Facilities

Facilities are one of the main means for children to want to learn. If the facilities are adequate, children will begin to be interested in learning. Learning is one way to find out what potential exists in students. Students at school do not all know their potential, so it is the facilities that will help them know their identity or talents. Students who already know their talents and potentials will hone them further with the facilities that have been provided at school. The minimum facilities in the school are physics laboratories, chemistry laboratories, biology laboratories, sports fields, wifi, computers, and social studies laboratories. These facilities must exist and be used by teachers to find student potential or develop student potential. Teachers must learn by utilizing various facilities in schools. For example, teachers must make practicum learning in the laboratory, teachers make learning media that ask students to access with computers. The development of students' self-potential carried out by other teachers is by providing intensive guidance to students, providing assistance to students who lack interest and motivation in learning, setting a good example, inviting students to jointly clean the school environment, carrying out spiritual refreshment activities every morning, holding repetitions for new students, holding extracurricular activities, and giving sanctions and reprimands to students (Amaliyah, A., & Rahmat, 2021).

3.7. Communicate effectively, empathetically and politely to students

A good teacher is a teacher who is always friendly and polite to his students. Teachers have 2 characters that must be mastered, namely strict discipline in class and friendly in communicating with students. Teachers can communicate effectively by actively listening to every word of

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students. Suppose the teacher pays full attention when students speak, and always uses clear and simple language. Teachers must use language that is easy for students to understand.

Teachers must also always try to show empathy so that effective communication with students can run smoothly. Teachers who are polite to students always try to give praise and support when students answer questions properly and correctly. In addition to the above, to demonstrate effective communication, teachers must be able to be open and honest, use positive body language, provide space for students to speak, be patient and tolerant. The above methods can be used to build a better relationship between teachers and students. Good communication between students and teachers can create a positive learning environment, and increase learning effectiveness. The teacher's ability to provide the right reward for the success of students makes students better understand the material being taught, in addition to the teacher's activities that communicate enthusiastically and earnestly in learning activities make students more motivated and easily understand the material (Putri, 2020).

1.8. Penerapan dan Pemanfaatan Evaluasi Proses dan Hasil Pembelajaran

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Evaluation of learning processes and outcomes is an important step to ensure the effectiveness of teaching and the achievement of educational goals. Teachers can evaluate learning in 3 ways, namely diagnostic evaluation, formative evaluation, and summative evaluation. Other evaluations can also be done by making a reflective journal at the end of each teaching session to evaluate what is already good and what needs to be improved. Evaluation can be done using an online learning platform that provides automatic evaluation features and at the same time to track student progress. Teachers can also ask students to work in groups and create collaborative projects that demonstrate their understanding and skills. Evaluation can also be done by self-evaluation, where students evaluate themselves and identify areas that need improvement. Students can also conduct peer assessments. Peer assessment to provide additional perspective on their performance. Evaluation aims to find out the level of student achievement in a learning process, as well as understand students about the extent to which they can provide assistance to student shortcomings, with the aim of placing students in more appropriate learning situations according to their needs. according to their ability level. Meanwhile, the function of evaluation is to help the

process, progress and development of student learning outcomes in a sustainable manner, as well as to be able to find out students' abilities and weaknesses in certain fields of study, as well as to provide information to parents/guardians of students regarding the determination of class promotion or the determination of student graduation (Idrus, 2019).

3.9. Reflective Actions in Improving the Quality of Teaching and Learning

Reflective action is a process in which teachers critically analyze their teaching practices to improve the quality of learning. Teachers can conduct flexible learning by taking daily notes after each teaching session, asking students to provide regular feedback through surveys, questionnaires, or open discussions. By implementing these measures, teachers can consistently improve the quality of learning they provide, as well as create a more effective and supportive learning environment for students. Through the reflective thinking process carried out by applying the four stages of a complete reflective thinking process, it can help teachers in becoming reflective individuals. The results of this reflection can help teachers to find solutions that can be applied to problems in the classroom. It is important for teachers to reflect, because being a reflective person is a real action for redeemed humans. By reflecting, people are aware of their mistakes, and continue to try to find solutions to their problems as concrete actions from themselves who want to change for the better (Manurung & Listiani, 2020).

Teachers must adapt to their learning activities and find the right learning strategies and technology to be used in the delivery of teaching materials (Denby and Holman, 2002). PCK is a framework that teachers need to have a deep understanding of the pedagogical components and structure of teaching materials. PCK is a complex form of integration of content knowledge (CK) and pedagogical ability (PK). PCK is an important framework that must be known by a teacher, because PCK will always be used in learning activities and related to students' interest in learning and understanding the material (Tondeur et al., 2017). Koehler and Mishra (2019) argue that PCK helps teachers understand and can use this form of knowledge in the teaching and learning process. Teachers need to know what and how they apply learning strategies or models in a unique context in their classrooms.

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The development of teachers' abilities towards PCK in ASEAN is influenced by national education policies which include government regulations and teacher competency activities in designing learning. The quality of learning will depend on learning activities, the way the material is delivered, and the way the teacher teaches. The challenge of this PCK can be seen from the suitability of learning strategies with teaching materials. A wise teacher must adapt the learning strategy to the characteristics of the material. However, for teachers who do not understand PCK, they will teach with the aim that the material is only delivered to students without looking at student activities in learning. Therefore, schools and organizers must have training courses or professional development programs for teachers and prospective teachers, especially professionals in the field of pedagogy and professionals in understanding teaching materials.

A good teacher is a teacher who is willing to develop learning strategies and adjust to the needs of students. Design thinking must be used for instruction-based classroom activities in preparing teachers in PCK. The state needs to set educational management goals by helping teachers know, understand and be able to use PCK in the teaching process (Blau, I. and Shamir-Inbal, 2017). Especially the teacher preparation program or pre-service teachers who are the younger generation in schools, who understand the development of new learning strategies and are enthusiastic about learning innovations in accordance with the demands of the 21st century. PCK's empirical studies of prospective science teachers show that all areas of knowledge show that they understand the integration of pedagogy, technology and bring different methods and ideas into the classroom learning environment. Teacher preparation programs need to pay attention to teacher competencies and embed PCK into the study program. While the nature of learners' learning is changing, teachers must adapt teaching strategies and they can utilize educational technology for effective teaching (Prachagool, V. and Nuangchalerm, 2019).

The Relationship of Pedagogical Content Knowledge (PCK) to Realize Sustainable Development Action

Pedagogical Content Knowledge (PCK) is an educational concept that emphasizes the ability of teachers to integrate content knowledge and pedagogy in a harmonious manner to create effective

learning (Siow Heng Loke et al., 2015; Zubaidah et al., 2023)). PCK has a central role in sustainable development action because it can help educators deliver educational materials related to sustainability in a way that is relevant, interesting, and meaningful for students. Teachers who have a strong PCK are able to bridge the gap between sustainability theory and real practice, so that students not only understand the concepts of sustainability, but are also motivated to take real actions in daily life. Based on the table 3, prospective students of Science teachers from the Philippines and Indonesia have a readiness that is very ready and quite ready more than 90%. This suggests that students who have PCK readiness have been considered able to bridge students to understand sustainability concepts and motivate them to take real action in their daily lives.

Education oriented towards sustainable development demands a multidisciplinary approach that combines social, environmental, and economic aspects (Araneo, 2024). Through PCK, teachers can design learning strategies that combine scientific knowledge, moral values, and practical skills. For example, in learning about climate change, a teacher with a good PCK can integrate scientific data on carbon emissions with discussions of environmental ethics and action-based projects, such as planting trees or reducing the use of plastics. Thus, PCK allows learning not only to be a means of knowledge transfer, but also a process of character formation that supports sustainable development.

PCK is also relevant in building students' critical awareness of global and local issues related to sustainable development. Teachers can use critical pedagogical approaches to help students understand the root causes of sustainability issues, such as social inequality, exploitation of natural resources, and pollution. Through this understanding, students are encouraged to think critically, find creative solutions, and take responsible collective action. PCK allows teachers to facilitate productive and collaborative dialogue in the classroom so that students feel they have an important role to play in sustainable development efforts (Forsler et al., 2024). In addition, PCK supports the development of 21st century skills, such as problem-solving, collaboration, and digital literacy, which are critical in realizing sustainable development (Shafie et al., 2019). In the learning process, teachers can utilize innovative technologies and methods to provide an authentic learning

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experience (Ramaila & Molwele, 2022). These innovative learning methods, for example, such as project-based learning and problem-based learning, can provide students with real learning experiences to provide meaningful learning. This approach not only increases student engagement, but also helps them understand the complexity of sustainability issues and the importance of cross-sectoral cooperation to address them.

PCK plays a key role in supporting education as a tool of social transformation for sustainable development (Forsler et al., 2024). With a strong PCK, teachers can create relevant, inspiring, and action-based learning, ultimately helping to shape an environmentally conscious, socially responsible, and empowered generation in the face of global challenges. In the long term, investing in the development of PCK for educators is a strategic step to strengthen the education system and achieve a vision of a more equitable, inclusive and sustainable world.

The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies. With a strong understanding of PCK, prospective teachers can design contextual, interdisciplinary, and meaningful learning, thereby equipping students with the awareness and skills to contribute to sustainable development. Therefore, improving the PCK competency of prospective science teachers must be a priority in teacher education to create a generation that is able to face global challenges and realize sustainable development goals.

CONCLUSION

This study reflects that 44.9% of Indonesian students and 58.5% of Filipino students who will work as prospective science teachers have pedagogical content knowledge (PCK) readiness. As many as 41.5% of Indonesian students and 49.3% of Filipino students are in the category of being quite ready to know and master pedagogical skills and the content of science materials. With a strong understanding of PCK, prospective teachers can design contextual, interdisciplinary, and

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meaningful learning, thereby equipping students with the awareness and skills to contribute to sustainable development. Improving the PCK competence of prospective science teachers must be a priority in teacher education to create a generation that is able to face global challenges and realize sustainable development goals.

The content of science material is always related to pedagogical skills, in this study the content of the material is always closely related to the 10 indicators of pedagogical ability which include 1) mastery of student character 2) understanding related to learning theories 3) being able to compile a curriculum 4) carrying out development activities 5) utilizing technology for learning media 6) Providing facilities to develop student potential 7) Communicating effectively, empathy and courtesy to students 8) Conducting assessments and evaluations of the learning process and results 9) Utilizing assessments and evaluation results 10) Carrying out reflective actions in improving the quality of teaching and learning.

The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies.

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Pedagogical Content Knowledge (PCK) of Sains Prospective Teachers in ASEAN to Realize Sustainable Development Action (SDGs)

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Student
Sains Teacher
SDGs

ABSTRAK

Calon guru IPA sangat penting untuk memiliki penguasaan terkait pengetahuan pedagogis (PK) dan pengetahuan material (CK) terkait materi IPA atau yang biasa kita kenal dengan Pengetahuan Konten Pedagogis (PCK) sebelum terjun ke dunia kerja. PCK merupakan pengetahuan wajib yang harus dikuasai oleh calon guru. Penelitian ini bertujuan untuk menganalisis kesiapan PCK bagi calon guru IPA di Indonesia dan Filipina. Penelitian ini akan menjelaskan terkait CK dan PK yang harus dikuasai oleh guru yang akan mengajar di kawasan ASEAN. Data ini dikumpulkan dengan melakukan survei terhadap 110 calon guru yang sedang melakukan praktik lapangan di sekolah-sekolah di Filipina dan Indonesia. Data juga diperkuat dengan melakukan wawancara dengan 6 calon guru di Indonesia dan 6 calon guru di Filipina. Data yang dikumpulkan terkait dengan apa yang mereka pahami dan siapkan dari segi pedagogi dan materi sains. Hasil penelitian ini menunjukkan bahwa kemampuan PCK mereka rata-rata pada level ready. Temuan penelitian ini menunjukkan bahwa guru harus meningkatkan pengetahuannya terkait pengetahuan muatan pedagogis (PCK) karena jumlah siswa sebagai calon guru IPA yang berada dalam kategori siap masih relatif rendah, yakni 44,9 -58,5%. Peningkatan PK dapat dilakukan dengan memberikan tambahan kursus pendidikan dan pelatihan pedagogis untuk meningkatkan keterampilan pedagogis. Peningkatan CK dapat dilakukan dengan menambahkan mata kuliah khusus untuk materi IPA di sekolah sebelum mereka berlatih mengajar ke sekolah. Kesiapan calon guru IPA dalam memahami Pedagogical Content Knowledge (PCK) berperan penting dalam mendukung aksi pembangunan berkelanjutan. PCK tidak hanya mencakup kemampuan calon guru untuk mengintegrasikan pengetahuan bahan ajar dan strategi pedagogis, tetapi juga kemampuan mereka dalam menyampaikan konsep ilmiah yang relevan dengan isu keberlanjutan, seperti perubahan iklim, konservasi sumber daya alam, dan teknologi ramah lingkungan.

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ABSTRACT

Prospective science teachers are very important to have mastery related to pedagogical knowledge (PK) and material knowledge (CK) related to Science or what we commonly know as Pedagogical Content Knowledge (PCK) before entering the world of work. PCK is mandatory knowledge that must be mastered by prospective teachers. This study aims to analyze the readiness of PCK for prospective science teachers in Indonesia and the Philippines. This research will explain related to CK and PK that must be mastered by teachers who will teach in the ASEAN region. This data was carried out by conducting a survey of 110 prospective teachers who are conducting field practice in schools in the Philippines and Indonesia. Data was also collected by conducting interviews with 6 prospective teachers in Indonesia and 6 prospective teachers in the Philippines. The data collected is related to what they understand and prepare in terms of pedagogy and science materials. The results of this study showed that their PCK ability was average at the ready level. The findings of this study show that teachers must improve their knowledge related to pedagogical content knowledge (PCK) because the number of students as prospective Science teachers who are in the ready category is still relatively low, namely 44,9 - 58,5%. Improving PK can be done by providing additional pedagogical education and training courses to improve pedagogical skills. Improving CK can be done by adding special courses for Science material in schools before they practice teaching to schools. The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies.

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INTRODUCTION

Education is a strategic field for prospective science teachers because it requires not only mastery of the material, but also pedagogical skills to guide students in facing the challenges of the 21st century. However, in practice, there is still a fundamental problem, namely the low readiness of prospective teachers in integrating content knowledge (CK) and pedagogical knowledge (PK) into science learning. This condition becomes relevant because the demands of the 21st century curriculum and the global agenda of the Sustainable Development Goals (SDGs) emphasize the importance of teachers who are able to develop meaningful, innovative, and sustainability-oriented learning. The new era of education in the school curriculum is currently centered on student centre

learning. Students are not required to have good learning results to get first place, but students are required to master a good learning process. In order for students to have a good learning process, a teacher must understand how to teach and how to make students understand the material by doing activities or practicums. The material that students receive from year to year will change along with the development of the times and technology, so that in this new era of education, students are not only required to master the material but must be able to carry out activities to find a material.

The dynamic development of science in accordance with the development of the times makes teachers always have to be creative in making learning activities. Learning activities must be adjusted to the demands of the times. To answer this, it is very important for teachers to master classroom management and the development of ever-changing materials that will be given to students. This is in accordance with the theory that states that the challenge to prepare for future life is by learning 21st century skills where children will be faced with uncertain situations in the future (Hong et al., 2019). Uncertainty in the future is related to the material that students will receive that is always changing and evolving. Changes in the material received by students must be in line with changes in the way a teacher teaches. If the change in material is taught in the way of teaching in the past, for example lectures, then students will not understand and learning does not make students actively search for the material themselves.

Pedagogical Content Knowledge (PCK) according to Shulman (1987) is to characterize teachers' knowledge to instructional explicitly with integrated pedagogy and content as well. PCK contains two main components, namely Content Knowledge (CK) and Pedagogical Knowledge (PK). First, CK describes the knowledge of prospective teachers regarding the subject matter of the material to be taught. Knowledge of this content is one of the most important components as a requirement to become a teacher (Shulman, 1986). Second, PK describes the knowledge of prospective teachers about mastery of practices, processes, strategies, procedures, and methods in the teaching and learning process (Shulman, 1986).

PCK merupakan ilmu penting yang harus dikuasai oleh calon guru sebagai dasar untuk membantu dan making it easier for students to understand difficult concepts. PCK can also improve knowledge and skills including critical thinking, creativity, communication and collaboration skills (Cetin-Berber, D. & Erdem, A, 2015). Teachers who master PCK are believed

to be able to create a fun learning atmosphere and make it easier for students to understand the material.

PCK is an idea where the delivery of material must be adjusted to the teacher's teaching method which is not monotonous and always changes every meeting. For example, the first day with the docovery learning model, the second day with the project-based learning model, and the third day with the cooperative learning model. Changes in teaching methods will make students interested in starting learning activities. Students will always want to know what new learning activities the teacher uses in each of their meetings. If the motivation of students in participating in learning activities has appeared, the learning material will be very easy for students to accept. PCK plays a very effective role in teacher development to achieve effective learning activities.

Pedagogical knowledge includes mastery of student characteristics, mastery of learning theories and principles of educational learning, curriculum development, educational learning activities, development of student potential, how to communicate, and mastery of student assessment and evaluation. Pedagogic competence includes 10 standards, namely 1) mastery of students' character. 2) understanding related to learning theories 3) being able to develop a curriculum. 4) carrying out development activities. 5) Utilizing technology for learning media. 6) providing facilities for the development of students' potential. 7) communicate effectively, empathetic and polite to students. 8) conduct assessments and evaluations of learning processes and outcomes. 9) utilizing the results of assessment and evaluation. 10) Carrying out reflective actions in improving the quality of teaching and learning (Kementerian Pendidikan Nasional Indonesia, 2007).

Philippines is a country that prioritizes teachers who have good pedagogical skills. Government regulations in the Philippines are also clear that there are 7 main domains for a teacher to be effective in organizing learning according to the demands of education in the 21st century. Qualified teachers in the Philippines need to possess the following characteristics: recognize the importance of mastery of content knowledge and its relevance within and across curriculum areas; provide a safe, secure, fair and supportive learning environment to increase student responsibility and achievement; building a learning environment that is responsive to the diversity of students; interact with national and local curriculum requirements; implementing various assessment tools and strategies in monitoring, evaluating, documenting and reporting on

students' needs, progress and achievements; establishing school-community partnerships that aim to enrich the learning environment, as well as community involvement in the educational process; Valuing personal growth and professional development and showing high personal respect for their profession by maintaining qualities that uphold the dignity of teaching such as caring, respectful and integrity (Philipines DepEd Order Number. 42, s, 2017).

A good teacher is a teacher who can involve students in all learning activities in the classroom. Teachers must understand the 10 pedagogic competency standards so that learning activities are more meaningful. PCK is knowledge about the pedagogical relationship with the learning materials that will be given to students. PCK is a basic ability for teacher ability development. The development of teachers in Indonesia is supported by teacher professional education (PPG) which must be pursued by education graduates. Teachers are expected to develop into a profession that can support 21st century skills and the development of technological advances by creating quality students. The concept of teacher education focuses on technology education that is integrated in PCK or pedagogical content knowledge (Shulman, 1986). Learning practices use PCK to acquire the knowledge and skills students need that are relevant to the content, culture, context and psychological role (Denby, D, and Holman, J , 2002). PCK is a science that really helps teachers to create a common ground between the material to be delivered at school, the content of learning, and pedagogical competence. Nuangchalerm (2020) shows that PCK can help teachers learn to be good at teaching and better understand pedagogical skills. Teachers who already know the content of the material must think about what learning model is suitable for use in learning activities so that all students can be active.

Science is a material that really needs a variety of learning models to make students understand the material. Prospective science teachers must be able to understand pedagogical skills and use these skills to teach a wide variety of science materials. The readiness of prospective teachers in terms of PCK will be very important to know to be able to find problems related to this. This research will be very important to produce conclusions related to the condition of prospective science teachers in Indonesia and the Philippines to find out the PCK. According to Shulman (1987), teacher preparation programs must combine pedagogical knowledge and content knowledge to teach and learn appropriately. PCK is the ability to combine knowledge of a particular discipline with science teaching. This makes teachers really understand the content and

turn it into appropriate teaching (Shulman, 1986). Students who are interested in learning activities will also begin to be interested in learning the material. The combination of fun learning activities and the material taught will be easily accepted by students if their hearts are happy.

Heibert et al (2007) proposed a teacher preparation framework to help develop teacher competencies in setting learning objectives, evaluating student performance, hypothesizing the relationship between learning materials and self-reflection teaching. Social changes and learning environments are pushing the trend of PCK to a higher level of use (Nuangchalerm, 2020). PCK is a science that must be mastered by prospective teachers to develop skills and professionalism in teaching. The combination of 2 elements, namely pedagogy and material content, is very basic so that teachers can work professionally. This study aims to analyze PCK in ASEAN education and connect PCK with prospective science teachers. The results of this research will be used as input for the Teacher Professional Education program in Indonesia and Philippines. The results of this research are also expected to be an input for universities to provide further knowledge related to PCK by combining it in courses.

Teachers in the future need to master a good understanding of how pedagogical knowledge and content can be effective in the learning process in the classroom. To answer this need, Koehler and Mishra (2019) introduced a conceptual framework called Pedagogical Content Knowledge (PCK) which was obtained from the addition of technology to Pedagogical Content Knowledge (PCK) which is a conceptual framework built by Shulman (1986). According to Karaca (2015), the development of the PCK model provides an overview for prospective teachers and academics that the model can help improve the ability to integrate technology in the learning process in the classroom to find out the latest material content. PCK as a relationship between pedagogical knowledge and content that is the basis of good teaching.

The content of the material that is interacted with good pedagogical skills will be able to help solve the problems faced by students in carrying out effective, innovative and fun learning. The integration of pedagogical skills in the delivery of teaching materials requires a structured and creative design in its application, in addition to that, the right approach is also needed in the learning implementation plan with the context of the material to be delivered. This PCK knowledge will be very meaningful for prospective teachers to form a teaching activity when they have entered the world of work.

The Sustainable Development Goals (SDGs) are a global agenda launched by the United Nations (UN) to achieve inclusive, sustainable, and environmentally sound development (Kleespies & Dierkes, 2022; Whittingham et al., 2023). The SDGs in goal no. 4 emphasize the importance of providing quality education that reaches all levels of society. SDGs-oriented education aims to equip students with knowledge, skills, values, and attitudes that support the achievement of sustainable development. This includes awareness of global issues, such as climate change, gender equality, social justice, and environmental conservation.

The implementation of the SDGs in learning is essential to ensure that future generations not only become academically competent individuals, but also socially and ecologically responsible. Therefore, teachers have a central role in integrating SDGs values into the learning process. Teachers are expected to be able to design learning tools that are relevant to SDGs issues, so that students can understand and apply these concepts in real life. However, the success of the integration of SDGs in learning is highly dependent on the readiness of teachers' pedagogical content knowledge (PCK). PCK is a framework that includes knowledge of the content to be taught, effective pedagogical strategies, and an understanding of students' needs and characteristics. In the context of implementing the SDGs, teachers' PCK must include the ability to identify learning topics relevant to the SDGs, develop teaching methods that motivate students to think critically and act solutive on global issues, and develop learning evaluations that can measure students' understanding of SDGs issues.

The readiness of teachers' PCK is a crucial aspect because not all teachers have adequate competence and experience in integrating the SDGs into learning tools. For this reason, training and professional development for teachers are necessary steps. This training must include an in-depth understanding of the SDGs, innovative teaching strategies, and assessment techniques that support SDGs-based learning. Thus, teachers can be more confident and skilled in designing learning that not only prioritizes academic achievement, but also shapes the character of students with a global perspective.

A number of previous studies have emphasized the importance of Pedagogical Content Knowledge (PCK) as the foundation of teacher professionalism (Shulman, 1986; 1987; Cetin-Berber & Erdem, 2015). Studies at the local level also show variations in the readiness of prospective teachers in mastering aspects of PCK, both in terms of pedagogy and scientific content

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(Nuangchalerm, 2020; Tondeur et al., 2017). However, the study generally still focuses only on technology integration or on one particular discipline and not many have conducted a comparative analysis across ASEAN countries. Based on this description, this study aims to analyze the readiness of Pedagogical Content Knowledge (PCK) of prospective science teachers in Indonesia and the Philippines, as well as identify challenges and opportunities for teacher professional development in the context of SDGs implementation.

RESEARCH METHOD

This study will use the research design of the explanatory sequential mixed method. The design of the sequential mixed method of explanation (also called the two-phase model; J. W. Creswell & Clark (2017) consists of first quantitative data collection and then qualitative data collection to help explain or elaborate the quantitative results. The reason for this approach is that the quantitative data and results provide an overview of the research problem; Further analysis, particularly through qualitative data collection, is necessary to refine, expand, or explain the general quantitative picture (Creswell, J., & Guetterman, 2018). The respondents of this study are students who will become prospective science teachers in 2 countries. The respondents consisted of 41 Indonesian students and 69 Philippines citizens.

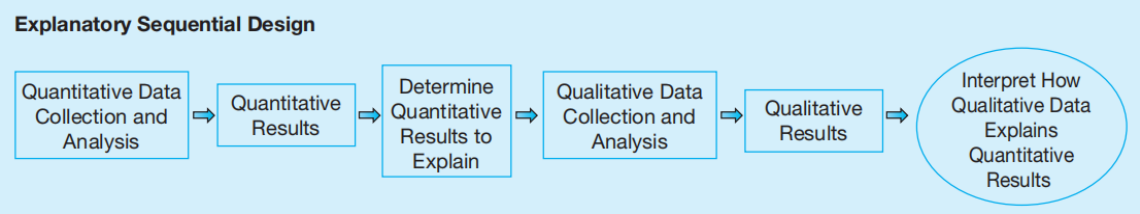

Figure 1. Explanatory Sequential Design

The analysis will be carried out in such a way that quantitative research is carried out first and then qualitative research will follow. Quantitative inquiry will be used to gather information on the readiness of prospective teachers in terms of technological readiness, pedagogy, and content knowledge. The qualitative investigation will continue after the participants with the least, the most readiness, and are being identified. The quantitative stage was in the form of a Likert scale questionnaire survey which was analyzed using descriptive statistics, followed by a qualitative stage in the form of semi-structured interviews with 12 prospective teachers (6 Indonesians, 6

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Philippines) who were selected from different readiness categories and analyzed through thematic analysis. The research subjects amounted to 110 prospective science teachers (41 Indonesians, 69 Filipinos) who were selected using purposive sampling techniques to represent the diversity of fields and teaching experiences. The questionnaire instrument was developed based on the framework of PCK Shulman (1986; 1987), validated through expert judgment. Data analysis was carried out with SPSS for quantitative and manual coding with a thematic matrix for qualitative.

RESULT

This research was conducted in two countries. These countries are Indonesia and the Philippines. The results of the research that we present also involve data from 2 countries. The results of this study will describe the condition of knowledge pedagogy readiness and knowledge content in Indonesia and the Philippines.

Table 1. Level of PK (Pedagogical Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	42	60.9	35	85.4
Moderately Ready	26	37.7	6	14.6
Not Ready	1	1.4	0	0
N=	69	100.0	41	100.0

Table 1 shows that from the Philippines there are 42 students who are ready to master pedagogical skills and apply pedagogical knowledge to the classroom, while in Indonesia there are 35 students who are in the ready category. Students who are quite ready to understand pedagogy from the Philippines are 26 people while Indonesia is 6 people. This fairly ready category shows that students have not mastered too many indicators that must be achieved in Pedagogy. The pedagogical knowledge assessed in this study is to see how to assess student performance in the classroom, how to teach, my teaching style for diverse students, how teachers use various teaching approaches, how to overcome student misunderstandings, how to manage the classroom, and how to adapt the learning approach to the student's condition.

Table 1 above explains about students who belong to the group that are not prepared for mastering pedagogical knowledge. There is 1 student from the Philippines who is still not ready to master pedagogical knowledge while from Indonesia there are no students who are in the category of not ready. The lack of pedagogical science means that students do not know much about how to teach, how to assess, how to make school administration. Overall, the results of this study reflect that 85.4% of Indonesian students and 60.9% of Filipino students who will work as prospective science teachers have readiness in pedagogical skills. Meanwhile, 14.6% of Indonesian students and 37.7% of Filipino students are in the fairly ready category. The category of students from the Philippines who do not have the readiness to master pedagogical knowledge is 1.4%.

Pedagogical Knowledge (PK) is the knowledge possessed by a teacher about effective learning principles, methods, and strategies. The indicators of Pedagogical Knowledge include several main aspects that include the ability to understand learning theories, design learning, manage classrooms, conduct assessments, and utilize educational technology. Teachers who have a good PK are able to understand how students learn, choose methods that suit their learning needs, and create a classroom environment that is conducive to learning. One of the main indicators is the understanding of prospective teachers about the student learning process. It includes knowledge of cognitive development theories, learning styles, motivations, and diverse learning needs. In addition, the ability to design learning is also an important indicator. Prospective teachers must be able to make a Learning Implementation Plan that is in accordance with the curriculum, choose relevant learning methods, and determine measurable learning goals.

Table 2. Level of CK (Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	37	53.6	21	51.2
Moderately Ready	30	43.5	20	48.8
Not Ready	2	2.9	0	0
N=	69	100.0	41	100.0

Table 2 shows that from the Philippines there are 37 students who are ready to understand the content of science material and implement science material that will be taught in class, while in Indonesia there are 21 students who are in the ready category. Students who are quite ready to understand the content of science material come from the Philippines totaling 30 people while Indonesia totals 20 people. This category of quite ready shows that students have not mastered the indicators that must be achieved in science knowledge material. The knowledge of the content of science material assessed in this study is that students have sufficient knowledge of physics, chemistry, biology. The second indicator is that students can integrate SETS (Science, Environment, Technology, and Society) in classroom learning. The third indicator is that students can match science material with the learning approach they want to use. The fourth indicator is that students can apply contextual learning, namely presenting science in real life. The fifth indicator is that students can apply their knowledge in the fields of Physics, Chemistry, and Biology and slice it into classroom learning. The eighth indicator is that students have extensive knowledge that is currently taught, namely biophysics, biochemistry, environmental balance, plants, animals, global warming.

Table 2 above also explains about students who belong to the unprepared group. There were 2 students from the Philippines while from Indonesia there were no students who were included in the unprepared category. The lack of pedagogy means that students do not know much about what science materials must be taught to students at school. In addition, they also lack understanding of the latest and current material that must be mastered if they want to become science teachers. Overall, the results of this study reflect that 53.6% of Indonesian students and 51.2% of Philippines students who will work as prospective science teachers have the readiness of science material content. Meanwhile, 48.8% of Indonesian students and 43.5% of Philippines students are in the category of being quite ready to know the content of science material. The category of students from the Philippines who are not ready is 2.9%.

Content knowledge (CK) includes an in-depth understanding of basic concepts in science, the ability to explain scientific phenomena, and the skill of integrating various branches of science such as physics, chemistry, biology, and earth science. CK is very important to ensure that prospective teachers are able to deliver material correctly, accurately, and relevantly. One of the main indicators of CK is mastery of basic concepts in science. Prospective teachers must

understand the main principles in science, such as the laws of physics, chemical cycles, the structure and function of living things, and geological processes. This knowledge must be holistic, which means that prospective teachers are able to see the connections between branches of science to provide students with a complete picture of the world of science. Another indicator of a prospective teacher mastering content knowledge is that the teacher can explain and model scientific phenomena clearly and logically. Prospective science teachers must be able to use easy-to-understand language to explain abstract concepts to students. For example, explaining the concept of gravitational force or photosynthesis with concrete examples that are relevant to daily life. This ability also includes the use of visual aids or practicum to clarify explanations.

The readiness of content knowledge can also be assessed from the ability of prospective teachers to relate science knowledge to the context of real life and global issues. For example, prospective teachers must be able to relate science concepts to environmental issues, such as climate change, pollution, or the energy crisis. This indicator shows that prospective teachers not only understand the theory, but also its relevance to student life and the challenges of the modern world. CK readiness indicators also include reflective abilities and knowledge updates. Science is a field that continues to develop, so prospective teachers must have a commitment to continue learning, keep up with the development of science, and update teaching materials according to new findings. Based on the above, the readiness of prospective science teachers is not only measured by the extent to which they master the material, but also from their ability to teach the material in a relevant, interesting, and contextual way.

Table 3. Level of PCK (Pedagogical Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	31	44.9	24	58.5
Moderately Ready	34	49.3	17	41.5
Not Ready	4	5.8	0	0
N=	69	100.0	41	100.0

PCK knowledge or Pedagogical Content Knowledge contains 2 major elements, namely pedagogical skills and knowledge of teaching materials. Table 3 above shows that from the

Philippines there are 31 students and from Indonesia there are 24 students who are categorized as ready to know pedagogical skills and the implementation of pedagogical science into science materials that will be taught to students. Students who are quite ready to understand PCK from the Philippines are 34 people while Indonesia is 17 people. This category of sufficient readiness indicates that students have not mastered the indicators that must be achieved in the PCK assessment. The things assessed in this study include how students choose an effective teaching approach to guide students' thinking and learning on science materials, how to choose different learning models to teach various topics on science materials, and how to choose different learning methods to teach various topics in science materials. science material. Table 3 above also explains about students who belong to the unprepared group. There are 4 students from the Philippines while from Indonesia there are no students who are included in the category of not ready. Not ready in terms of PCK means that students do not know much about how to connect the learning approach with the teaching materials that will be delivered to students. Overall, the results of this study reflect that 44.9% of Indonesian students and 58.5% of Filipino students who will work as prospective science teachers have pedagogical readiness and science material content. Meanwhile, 41.5% of Indonesian students and 49.3% of Filipino students are included in the category of being quite ready to know pedagogical skills and the content of science materials. The category of students from the Philippines who are not ready is 5.8%.

The data above shows that practicum activities in learning have not been carried out perfectly by prospective science teachers in two countries. It can be seen that only 44.9% of prospective science teachers in the Philippines and 58.5% of science teachers in Indonesia are ready to understand Pedagogy and Material Material. Students who are ready are those who are worthy of teaching in the school. Other students who are not ready should be guided first and given training until they are ready and master the PCK to be able to enter school. Practice and learning materials seem to be less seen as an absolute requirement for students to be ready to teach and become prospective teachers in schools.

DISCUSSION

The results of this study are in line with the findings of Nuangchalerm (2020) in Thailand and Tondeur et al. (2017) which show that the readiness of prospective teachers in the ASEAN

region still varies and needs further strengthening. A practical implication that can be drawn is the need for teacher education programs to emphasize the integration of CK and PK in the curriculum, accompanied by policies that support PCK based and SDGs oriented ASEAN crossborder training. In addition, the curriculum in microteaching courses also needs to include a sustainability context so that prospective teachers are accustomed to integrating global issues in their learning practices.

Pedagogical Knowledge (PK) is the knowledge possessed by a teacher about effective learning principles, methods, and strategies. The indicators of Pedagogical Knowledge include several main aspects that include the ability to understand learning theories, design learning, manage classrooms, conduct assessments, and utilize educational technology. Teachers who have a good PK are able to understand how students learn, choose methods that suit their learning needs, and create a classroom environment that is conducive to learning. One of the main indicators is the understanding of prospective teachers about the student learning process. It includes knowledge of cognitive development theories, learning styles, motivations, and diverse learning needs. In addition, the ability to design learning is also an important indicator. Prospective teachers must be able to make a Learning Implementation Plan that is in accordance with the curriculum, choose relevant learning methods, and determine measurable learning goals.

Content knowledge (CK) includes an in-depth understanding of basic concepts in science, the ability to explain scientific phenomena, and the skill of integrating various branches of science such as physics, chemistry, biology, and earth science. CK is very important to ensure that prospective teachers are able to deliver material correctly, accurately, and relevantly. One of the main indicators of CK is mastery of basic concepts in science. Prospective teachers must understand the main principles in science, such as the laws of physics, chemical cycles, the structure and function of living things, and geological processes. This knowledge must be holistic, which means that prospective teachers are able to see the connections between branches of science to provide students with a complete picture of the world of science. Another indicator of a prospective teacher mastering content knowledge is that the teacher can explain and model scientific phenomena clearly and logically. Prospective science teachers must be able to use easy-to-understand language to explain abstract concepts to students. For example, explaining the

concept of gravitational force or photosynthesis with concrete examples that are relevant to daily life. This ability also includes the use of visual aids or practicum to clarify explanations.

The readiness of content knowledge can also be assessed from the ability of prospective teachers to relate science knowledge to the context of real life and global issues. For example, prospective teachers must be able to relate science concepts to environmental issues, such as climate change, pollution, or the energy crisis. This indicator shows that prospective teachers not only understand the theory, but also its relevance to student life and the challenges of the modern world. CK readiness indicators also include reflective abilities and knowledge updates. Science is a field that continues to develop, so prospective teachers must have a commitment to continue learning, keep up with the development of science, and update teaching materials according to new findings. Based on the above, the readiness of prospective science teachers is not only measured by the extent to which they master the material, but also from their ability to teach the material in a relevant, interesting, and contextual way.

Understanding pedagogy or PK is a requirement so that students can choose the right learning strategy to teach the material. Understanding of teaching materials or CK is also a basic requirement so that students are ready to teach various materials that will be given at school according to their level. If PK and CK have not been mastered, what happens is that prospective teachers will always focus on the content and learning materials only and lack pedagogical strategies so that learning becomes boring because there are few student learning activities. Pedagogical Content Knowledge (PCK) is a combination of mastery of material (content knowledge) and the ability to teach it (pedagogical knowledge) effectively. PCK indicators include the ability of prospective teachers to understand the concept of teaching materials in depth, know the best way to deliver the material to students, and recognize the learning challenges faced by students. PCK integrates knowledge about "what is taught" and "how to teach" to make learning more effective and meaningful. The readiness of Pedagogical Content Knowledge of prospective teachers can be reviewed from several main indicators. First, the ability to identify important concepts in teaching materials that are often misconceptions for students. Prospective teachers must understand learning difficulties that may arise and be able to design learning strategies that can overcome these difficulties. Second, the ability to choose learning methods that are in accordance with the material and student needs, for example using experiments, case studies, or project-based approaches for

scientific materials such as science. In addition, the mastery of prospective teachers with learning aids, such as educational technology or interactive media, is also an important part of PCK readiness. Another indicator is the ability of prospective teachers to connect teaching materials with the context of students' daily lives. This aims to enable students to understand the relevance of the material they learn to the real world. The readiness of PCK can also be seen from the reflective ability of prospective teachers to evaluate the effectiveness of their teaching strategies and make improvements based on student input or learning outcomes. Thus, prospective teachers who have PCK readiness are able to teach material accurately, relevantly, and interestingly, while ensuring that students are actively involved in the learning process.

Content knowledge is now an uncertainty because information technology transfers big data excessively to everyone. Excessive material is sometimes not in accordance with the mental development of a student. Students have their own material packages that must be taught according to their age. This content knowledge should be the basic capital for students to be able to teach in schools. This content knowledge includes an understanding of the material, explaining what material will be taught at the beginning of the semester, and what material will be taught afterwards. If students are not ready to understand the material, then further learning will stop. For example, the material that will be taught in the initial class is basic material such as biodiversity and ecosystems, while the advanced material that must be taught is cells, reproductive systems, and genetics. The material should not be reversed from the way it is given to students because the material is a form of continuous learning. Content seems to be outdated and technology has changed.

The relationship between pedagogical knowledge and content knowledge will be explained in more detail on each indicator of pedagogical ability which includes 10 things. These indicators will be associated with the content of science material that will be taught to students. Each indicator of pedagogical ability has its own relationship with content knowledge. Pedagogical ability is determined by 10 indicators. Teachers must master these indicators to be able to declare themselves knowledgeable and capable of being professional in pedagogical skills. The following will be described 10 indicators of pedagogical ability according to the Indonesian Ministry of National Education (2007), including 1) mastery of student character. 2) understanding related to

learning theories 3) being able to develop a curriculum. 4) carrying out development activities. 5) utilizing technology for learning media. 6) providing facilities to develop students' potential. 7) communicate effectively, empathetic and polite to students. 8) conduct assessments and evaluations of learning processes and outcomes. 9) utilizing the results of assessment and evaluation. 10) Carry out reflective actions in improving the quality of teaching and learning. The 10 indicators of pedagogical ability will be discussed with content knowledge in science material to be able to find out the unity of pedagogical knowledge (PK) and content knowledge or (CK).

3.1. Mastery Of Student Character

Mastery of students' character is very important in pedagogical ability. A good teacher is a teacher who can understand the condition of his students. The condition of the student is what is meant by the character of the student. Teachers' pedagogic competence in Indonesia requires teachers to be able to understand the development of student psychology by looking at their characters. The pedagogical competence of teachers in the Philippines also states that teachers must be able to appreciate the personal growth of students. This means that a teacher must be able to understand the development of student psychology to be able to determine the right learning strategy. The character of students is directly proportional to the learning model used. Student characteristics are very important for educators to know, because this is very important to be used as a reference in formulating learning strategies. Learning strategies are prepared by teachers and implemented through learning methods to students so that learning goals can be achieved effectively and efficiently. The development of students' self-potential carried out by teachers can be done in several ways, namely by providing intensive guidance to students, providing assistance to underprivileged students, providing good examples, inviting students to jointly clean the school environment, carrying out congregational dhuha prayers every Friday morning, conducting tests for new students, holding extracurricular activities, and giving sanctions and awards to students. Then what is an obstacle for teachers in developing students' self-potential is students' innate attitudes, interests and motivations, teacher competence, school facilities and infrastructure, and the environment around students (Septianti, N., & Afiani, R, 2020).

The character of students combined with the right learning model will make it easier for teachers to convey learning materials. For example, if the teacher wants to deliver photosynthesis material on leaves to students with active characters, then the learning model chosen is based on practicum or discovery. The discovery-based learning model will make active students feel facilitated to do practicum in finding new materials related to photosynthesis.

3.2. Understanding Related Learning Theories

Learning theory is a guideline for all teachers in carrying out learning. Learning theory contains the meaning of learning, the meaning of learning, and the types of learning methods from various experts. Teachers must understand the meaning of this learning theory starting from behavioristic, constructivistic, cognitivism, and humanistic theories. A teacher who understands learning theory will understand how to guide learning so that students can easily accept the material. Pedagogical learning in the Philippines requires professional teachers to understand the importance of mastery of knowledge, content, and its relevance within and throughout the curriculum (Philippine DepEd Order No. 42, 2017). Teachers in Indonesia are also required to master competencies related to understanding learning theories. Learning theory is the foundation of a learning process that leads to the formation of learning conditions. Therefore, the existence of learning theories will provide convenience for teachers in implementing the learning model that will be implemented and will help students in learning (Saefiana et al., 2020). Learning theory will provide an understanding to a teacher about a child's learning style. The right learning style used by a student will make it easier for him to understand the material. A student has a behavioristic learning style, so he will easily understand abstract material. The abstract material, for example, is virus material that will be understood if memorized repeatedly.

3.3. Curriculum Development

The curriculum is the main reference for a school in organizing learning. A good curriculum is a curriculum that is always developed every year. Curriculum development aims to adapt education to social changes as well as explore previously untouched knowledge (Harmita, D., & Aly, 2023). Curriculum development must be carried out by a teacher to be able to update the curriculum in accordance with technological developments and the development of the times. Teachers in the

Philippines under the regulations of the Department of Education of the Republic of the Philippines must understand how to translate the content of the curriculum into learning activities that are relevant to students and based on the principles of effective teaching and learning. This is also in line with what teachers in Indonesia must do, teachers in Indonesia must understand the principles of curriculum development. Curriculum development is also related to determining learning objectives. Teachers in determining learning objectives in the curriculum must understand the teaching materials. The curriculum contains all the learning objectives achieved so that students can understand and accept all the material. The content of science material must be well understood by a teacher so that the curriculum prepared is effective and efficient for students. Without knowledge of the content, a teacher cannot compile a curriculum properly.

3.4. Implementation of Development Activities

The development referred to here is the development of teachers' professional abilities. Although teachers have already given lectures when they want to earn a bachelor's degree, their competencies must always be honed to keep up with the demands of the ever-evolving world of education. Efforts that can be made to improve teacher professionalism are through the adoption of innovation or the development of creativity in the use of educational technology that utilizes the latest communication and information technology to develop teacher professionalism competencies (Zahara et al., 2024). In addition, development activities that must always be followed by teachers are the development of the ability to make learning media, workshops on making evaluation instruments, curriculum development workshops, learning model development workshops, and various types of learning support workshops.

3.5. Utilization of Technology for Learning Media

The use of technology in learning media can provide many benefits for the learning process. Technology is one of the tools that is often used as a learning medium apart from the practical side. Theuse of technology in learning is also included in the demands of the world of education. Theuse of technology is also a special attraction for students, because students tend to be more

enthusiastic in learning. Learning media is a way to channel trust between teachers and students, trust here means subject matter in which there is a message that must be understood by students, therefore the selection of learning media is also very important so that the message is conveyed by students. Teachers can convey material optimally through learning media and students can understand the message conveyed by the teacher (Suminar, 2019). Here are some activities that teachers can do in utilizing technology as a learning medium such as online learning, the use of multimedia, the use of social media as a learning resource, e-books and online articles. Online learning includes the use of platforms such as Google Classroom, Zoom, or Microsoft Teams to host online classes. Information technology can also be used as a medium to deliver assignments and exams online using an LMS (Learning Management System) platform such as the moodle application. The use of Multimedia can be used tocreate and display learning videos in explaining difficult concepts. Theuseof animationand simulation with multimedia can be used to clarify abstract or complex material. E-Books and onlinerticles can also be used by teachers as additional reference materials as well as directing students to online educational resources.

3.6. Student Potential Development Facilities

Facilities are one of the main means for children to want to learn. If the facilities are adequate, children will begin to be interested in learning. Learning is one way to find out what potential exists in students. Students at school do not all know their potential, so it is the facilities that will help them know their identity or talents. Students who already know their talents and potentials will hone them further with the facilities that have been provided at school. The minimum facilities in the school are physics laboratories, chemistry laboratories, biology laboratories, sports fields, wifi, computers, and social studies laboratories. These facilities must exist and be used by teachers to find student potential or develop student potential. Teachers must learn by utilizing various facilities in schools. For example, teachers must make practicum learning in the laboratory, teachers make learning media that ask students to access with computers. The development of students' self-potential carried out by other teachers is by providing intensive guidance to students, providing assistance to students who lack interest and motivation in learning, setting a good example, inviting students to jointly clean the school environment, carrying out spiritual

refreshment activities every morning, holding repetitions for new students, holding extracurricular activities, and giving sanctions and reprimands to students (Amaliyah, A., & Rahmat, 2021).

3.7. Communicate effectively, empathetically and politely to students

A good teacher is a teacher who is always friendly and polite to his students. Teachers have 2 characters that must be mastered, namely strict discipline in class and friendly in communicating with students. Teachers can communicate effectively by actively listening to every word of students. Suppose the teacher pays full attention when students speak, and always uses clear and simple language. Teachers must use language that is easy for students to understand.

Teachers must also always try to show empathy so that effective communication with students can run smoothly. Teachers who are polite to students always try to give praise and support when students answer questions properly and correctly. In addition to the above, to demonstrate effective communication, teachers must be able to be open and honest, use positive body language, provide space for students to speak, be patient and tolerant. The above methods can be used to build a better relationship between teachers and students. Good communication between students and teachers can create a positive learning environment, and increase learning effectiveness. The teacher's ability to provide the right reward for the success of students makes students better understand the material being taught, in addition to the teacher's activities that communicate enthusiastically and earnestly in learning activities make students more motivated and easily understand the material (Putri, 2020).

3.8 Application and Utilization of Evaluation of Learning Processes and Outcomes

Evaluation of learning processes and outcomes is an important step to ensure the effectiveness of teaching and the achievement of educational goals. Teachers can evaluate learning in 3 ways, namely diagnostic evaluation, formative evaluation, and summative evaluation. Other evaluations can also be done by making a reflective journal at the end of each teaching session to evaluate what is already good and what needs to be improved. Evaluation can be done using an online learning platform that provides automatic evaluation features and at the same time to track student

progress. Teachers can also ask students to work in groups and create collaborative projects that demonstrate their understanding and skills. Evaluation can also be done by self-evaluation, where students evaluate themselves and identify areas that need improvement. Students can also conduct peer assessments. Peer assessment to provide additional perspective on their performance. Evaluation aims to find out the level of student achievement in a learning process, as well as understand students about the extent to which they can provide assistance to student shortcomings, with the aim of placing students in more appropriate learning situations according to their needs. according to their ability level. Meanwhile, the function of evaluation is to help the process, progress and development of student learning outcomes in a sustainable manner, as well as to be able to find out students' abilities and weaknesses in certain fields of study, as well as to provide information to parents/guardians of students regarding the determination of class promotion or the determination of student graduation (Idrus, 2019).

3.9. Reflective Actions in Improving the Quality of Teaching and Learning

Reflective action is a process in which teachers critically analyze their teaching practices to improve the quality of learning. Teachers can conduct flexible learning by taking daily notes after each teaching session, asking students to provide regular feedback through surveys, questionnaires, or open discussions. By implementing these measures, teachers can consistently improve the quality of learning they provide, as well as create a more effective and supportive learning environment for students. Through the reflective thinking process carried out by applying the four stages of a complete reflective thinking process, it can help teachers in becoming reflective individuals. The results of this reflection can help teachers to find solutions that can be applied to problems in the classroom. It is important for teachers to reflect, because being a reflective person is a real action for redeemed humans. By reflecting, people are aware of their mistakes, and continue to try to find solutions to their problems as concrete actions from themselves who want to change for the better (Manurung & Listiani, 2020).

Teachers must adapt to their learning activities and find the right learning strategies and technology to be used in the delivery of teaching materials (Denby and Holman, 2002). PCK is a framework that teachers need to have a deep understanding of the pedagogical components and structure of

teaching materials. PCK is a complex form of integration of content knowledge (CK) and pedagogical ability (PK). PCK is an important framework that must be known by a teacher, because PCK will always be used in learning activities and related to students' interest in learning and understanding the material (Tondeur et al., 2017). Koehler and Mishra (2019) argue that PCK helps teachers understand and can use this form of knowledge in the teaching and learning process. Teachers need to know what and how they apply learning strategies or models in a unique context in their classrooms.

The development of teachers' abilities towards PCK in ASEAN is influenced by national education policies which include government regulations and teacher competency activities in designing learning. The quality of learning will depend on learning activities, the way the material is delivered, and the way the teacher teaches. The challenge of this PCK can be seen from the suitability of learning strategies with teaching materials. A wise teacher must adapt the learning strategy to the characteristics of the material. However, for teachers who do not understand PCK, they will teach with the aim that the material is only delivered to students without looking at student activities in learning. Therefore, schools and organizers must have training courses or professional development programs for teachers and prospective teachers, especially professionals in the field of pedagogy and professionals in understanding teaching materials.

A good teacher is a teacher who is willing to develop learning strategies and adjust to the needs of students. Design thinking must be used for instruction-based classroom activities in preparing teachers in PCK. The state needs to set educational management goals by helping teachers know, understand and be able to use PCK in the teaching process (Blau, I. and Shamir-Inbal, 2017). Especially the teacher preparation program or pre-service teachers who are the younger generation in schools, who understand the development of new learning strategies and are enthusiastic about learning innovations in accordance with the demands of the 21st century. PCK's empirical studies of prospective science teachers show that all areas of knowledge show that they understand the integration of pedagogy, technology and bring different methods and ideas into the classroom learning environment. Teacher preparation programs need to pay attention to teacher competencies and embed PCK into the study program. While the nature of learners' learning is changing, teachers must adapt teaching strategies and they can utilize educational technology for effective teaching (Prachagool, V. and Nuangchalerm, 2019).

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The Relationship of Pedagogical Content Knowledge (PCK) to Realize Sustainable Development Action

Pedagogical Content Knowledge (PCK) is an educational concept that emphasizes the ability of teachers to integrate content knowledge and pedagogy in a harmonious manner to create effective learning (Siow Heng Loke et al., 2015; Zubaidah et al., 2023)). PCK has a central role in sustainable development action because it can help educators deliver educational materials related to sustainability in a way that is relevant, interesting, and meaningful for students. Teachers who have a strong PCK are able to bridge the gap between sustainability theory and real practice, so that students not only understand the concepts of sustainability, but are also motivated to take real actions in daily life. Based on the table 3, prospective students of Science teachers from the Philippines and Indonesia have a readiness that is very ready and quite ready more than 90%. This suggests that students who have PCK readiness have been considered able to bridge students to understand sustainability concepts and motivate them to take real action in their daily lives.

Education oriented towards sustainable development demands a multidisciplinary approach that combines social, environmental, and economic aspects (Araneo, 2024). Through PCK, teachers can design learning strategies that combine scientific knowledge, moral values, and practical skills. For example, in learning about climate change, a teacher with a good PCK can integrate scientific data on carbon emissions with discussions of environmental ethics and action-based projects, such as planting trees or reducing the use of plastics. Thus, PCK allows learning not only to be a means of knowledge transfer, but also a process of character formation that supports sustainable development.

PCK is also relevant in building students' critical awareness of global and local issues related to sustainable development. Teachers can use critical pedagogical approaches to help students understand the root causes of sustainability issues, such as social inequality, exploitation of natural

resources, and pollution. Through this understanding, students are encouraged to think critically, find creative solutions, and take responsible collective action. PCK allows teachers to facilitate productive and collaborative dialogue in the classroom so that students feel they have an important role to play in sustainable development efforts (Forsler et al., 2024). In addition, PCK supports the development of 21st century skills, such as problem-solving, collaboration, and digital literacy, which are critical in realizing sustainable development (Shafie et al., 2019). In the learning process, teachers can utilize innovative technologies and methods to provide an authentic learning experience (Ramaila & Molwele, 2022). These innovative learning methods, for example, such as project-based learning and problem-based learning, can provide students with real learning experiences to provide meaningful learning. This approach not only increases student engagement, but also helps them understand the complexity of sustainability issues and the importance of cross-sectoral cooperation to address them.

PCK plays a key role in supporting education as a tool of social transformation for sustainable development (Forsler et al., 2024). With a strong PCK, teachers can create relevant, inspiring, and action-based learning, ultimately helping to shape an environmentally conscious, socially responsible, and empowered generation in the face of global challenges. In the long term, investing in the development of PCK for educators is a strategic step to strengthen the education system and achieve a vision of a more equitable, inclusive and sustainable world.

The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies. With a strong understanding of PCK, prospective teachers can design contextual, interdisciplinary, and meaningful learning, thereby equipping students with the awareness and skills to contribute to sustainable development. Therefore, improving the PCK competency of

prospective science teachers must be a priority in teacher education to create a generation that is able to face global challenges and realize sustainable development goals.

CONCLUSION

This study shows that the readiness of PCK for science teacher candidates in Indonesia and the Philippines is still at a moderate level, with significant variation between countries. The contribution of this research lies in the use of mixed methods that integrate quantitative and qualitative data to provide a comprehensive picture. Theoretically, this study enriches cross-border studies on PCK in the context of ASEAN. Practically, the results of the research are the basis for the PPG program and teacher education policies to strengthen the integration of CK and PK, especially in facing the demands of the SDGs. This research reflects that 44.9% of Indonesian students and 58.5% of Filipino students who will work as prospective science teachers have pedagogical readiness and content of science materials (PCK). As many as 41.5% of Indonesian students and 49.3% of Filipino students are in the category of being quite ready to know and master pedagogical skills and the content of science materials. The category of students from the Philippines who are categorized as unprepared is 5.8% mastering the pedagogical skills and content of SS material. The content of science material is always related to pedagogical ability, in this study the content of the material is always closely related to the 10 indicators of pedagogical ability which include 1) mastery of students' character 2) understanding related to learning theories 3) being able to develop a curriculum 4) carrying out development activities 5) utilizing technology for learning media 6) Providing facilities to develop students' potential 7) Communicating effectively, empathy and courtesy to students 8) Assessing and evaluating the learning process and results 9) Utilizing assessments and evaluation results 10) Implementing reflective actions in improving the quality of teaching and learning.

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Pedagogical Content Knowledge (PCK) of Prospective Science Teachers in ASEAN to Realize Sustainable Development Action

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ABSTRACT

Prospective science teachers are very important to have mastery related to pedagogical knowledge (PK) and material knowledge (CK) related to Science or what we commonly know as Pedagogical Content Knowledge (PCK) before entering the world of work. PCK is mandatory knowledge that must be mastered by prospective teachers. This study aims to analyze the readiness of PCK for prospective science teachers in Indonesia and the Philippines. This research will explain related to CK and PK that must be mastered by teachers who will teach in the ASEAN region. This data was carried out by conducting a survey of 110 prospective teachers who are conducting field practice in schools in the Philippines and Indonesia. Data was also collected by conducting interviews with 6 prospective teachers in Indonesia and 6 prospective teachers in the Philippines. The data collected is related to what they understand and prepare in terms of pedagogy and science materials. The results of this study showed that their PCK ability was average at the ready level. The findings of this study show that teachers must improve their knowledge related to pedagogical content knowledge (PCK) because the number of students as prospective Science teachers who are in the ready category is still relatively low, namely 44,9 - 58,5%. Improving PK can be done by providing additional pedagogical education and training courses to improve pedagogical skills. Improving CK can be done by adding special courses for Science material in schools before they practice teaching to schools. The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies.

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INTRODUCTION

Education is a strategic field for prospective science teachers because it requires not only mastery of the material, but also pedagogical skills to guide students in facing the challenges of the 21st century. However, in practice, there is still a fundamental problem, namely the low readiness of prospective teachers in integrating content knowledge (CK) and pedagogical knowledge (PK) into science learning. This condition becomes relevant because the demands of the 21st century curriculum and the global agenda of the Sustainable Development Goals (SDGs) emphasize the importance of teachers who are able to develop meaningful, innovative, and sustainability-oriented learning. The new era of education in the school curriculum is currently centered on student centre learning. Students are not required to have good learning results to get first place, but students are required to master a good learning process. In order for students to have a good learning process, a teacher must understand how to teach and how to make students understand the material by doing activities or practicums. The material that students receive from year to year will change along with the development of the times and technology, so that in this new era of education, students are not only required to master the material but must be able to carry out activities to find a material.

The dynamic development of science in accordance with the development of the times makes teachers always have to be creative in making learning activities. Learning activities must be adjusted to the demands of the times. To answer this, it is very important for teachers to master classroom management and the development of ever-changing materials that will be given to students. This is in accordance with the theory that states that the challenge to prepare for future life is by learning 21st century skills where children will be faced with uncertain situations in the future (Hong et al., 2019). Uncertainty in the future is related to the material that students will receive that is always changing and evolving. Changes in the material received by students must be in line with changes in the way a teacher teaches. If the change in material is taught in the way of teaching in the past, for example lectures, then students will not understand and learning does not make students actively search for the material themselves.

Pedagogical Content Knowledge (PCK) according to Shulman (1987) is to characterize teachers' knowledge to instructional explicitly with integrated pedagogy and content as well. PCK contains two main components, namely Content Knowledge (CK) and Pedagogical Knowledge (PK). First, CK describes the knowledge of prospective teachers regarding the subject matter of

the material to be taught. Knowledge of this content is one of the most important components as a requirement to become a teacher (Shulman, 1986). Second, PK describes the knowledge of prospective teachers about mastery of practices, processes, strategies, procedures, and methods in the teaching and learning process (Shulman, 1986). Pedagogic competence includes 10 standards, namely 1) mastery of students' character. 2) understanding related to learning theories 3) being able to develop a curriculum. 4) carrying out development activities. 5) Utilizing technology for learning media. 6) providing facilities for the development of students' potential. 7) communicate effectively, empathetic and polite to students. 8) conduct assessments and evaluations of learning processes and outcomes. 9) utilizing the results of assessment and evaluation. 10) Carrying out reflective actions in improving the quality of teaching and learning (Kementerian Pendidikan Nasional Indonesia, 2007).

Philippines is a country that prioritizes teachers who have good pedagogical skills. Government regulations in the Philippines are also clear that there are 7 main domains for a teacher to be effective in organizing learning according to the demands of education in the 21st century. Qualified teachers in the Philippines need to possess the following characteristics: recognize the importance of mastery of content knowledge and its relevance within and across curriculum areas; provide a safe, secure, fair and supportive learning environment to increase student responsibility and achievement; building a learning environment that is responsive to the diversity of students; interact with national and local curriculum requirements; implementing various assessment tools and strategies in monitoring, evaluating, documenting and reporting on students' needs, progress and achievements; establishing school-community partnerships that aim to enrich the learning environment, as well as community involvement in the educational process; Valuing personal growth and professional development and showing high personal respect for their profession by maintaining qualities that uphold the dignity of teaching such as caring, respectful and integrity (Philipines DepEd Order Number. 42, s, 2017).

A good teacher is a teacher who can involve students in all learning activities in the classroom. Teachers must understand the 10 pedagogic competency standards so that learning activities are more meaningful. PCK is knowledge about the pedagogical relationship with the learning materials that will be given to students. PCK is a basic ability for teacher ability development. The development of teachers in Indonesia is supported by teacher professional education which must be pursued by education graduates. Teachers are expected to develop into

a profession that can support 21st century skills and the development of technological advances by creating quality students. The concept of teacher education focuses on technology education that is integrated in PCK or pedagogical content knowledge (Shulman, 1986). Learning practices use PCK to acquire the knowledge and skills students need that are relevant to the content, culture, context and psychological role (Denby, D, and Holman, J , 2002). PCK is a science that really helps teachers to create a common ground between the material to be delivered at school, the content of learning, and pedagogical competence. Nuangchalerm (2020) shows that PCK can help teachers learn to be good at teaching and better understand pedagogical skills. Teachers who already know the content of the material must think about what learning model is suitable for use in learning activities so that all students can be active.

Science is a material that really needs a variety of learning models to make students understand the material. Prospective science teachers must be able to understand pedagogical skills and use these skills to teach a wide variety of science materials. The readiness of prospective teachers in terms of PCK will be very important to know to be able to find problems related to this. This research will be very important to produce conclusions related to the condition of prospective science teachers in Indonesia and the Philippines to find out the PCK. Heibert et al (2007) proposed a teacher preparation framework to help develop teacher competencies in setting learning objectives, evaluating student performance, hypothesizing the relationship between learning materials and self-reflection teaching. Social changes and learning environments are pushing the trend of PCK to a higher level of use (Nuangchalerm, 2020). PCK is a science that must be mastered by prospective teachers to develop skills and professionalism in teaching. The combination of 2 elements, namely pedagogy and material content, is very basic so that teachers can work professionally. This study aims to analyze PCK in ASEAN education and connect PCK with prospective science teachers. The results of this research will be used as input for the Teacher Professional Education program in Indonesia and Philippines. The results of this research are also expected to be an input for universities to provide further knowledge related to PCK by combining it in courses.

The content of the material that is interacted with good pedagogical skills will be able to help solve the problems faced by students in carrying out effective, innovative and fun learning. The integration of pedagogical skills in the delivery of teaching materials requires a structured and creative design in its application, in addition to that, the right approach is also needed in the

learning implementation plan with the context of the material to be delivered. This PCK knowledge will be very meaningful for prospective teachers to form a teaching activity when they have entered the world of work.

The Sustainable Development Goals (SDGs) are a global agenda launched by the United Nations (UN) to achieve inclusive, sustainable, and environmentally sound development (Kleespies & Dierkes, 2022; Whittingham et al., 2023). The SDGs in goal no. 4 emphasize the importance of providing quality education that reaches all levels of society. SDGs-oriented education aims to equip students with knowledge, skills, values, and attitudes that support the achievement of sustainable development. This includes awareness of global issues, such as climate change, gender equality, social justice, and environmental conservation.

The implementation of the SDGs in learning is essential to ensure that future generations not only become academically competent individuals, but also socially and ecologically responsible. Therefore, teachers have a central role in integrating SDGs values into the learning process. Teachers are expected to be able to design learning tools that are relevant to SDGs issues, so that students can understand and apply these concepts in real life. However, the success of the integration of SDGs in learning is highly dependent on the readiness of teachers' pedagogical content knowledge (PCK). PCK is a framework that includes knowledge of the content to be taught, effective pedagogical strategies, and an understanding of students' needs and characteristics. In the context of implementing the SDGs, teachers' PCK must include the ability to identify learning topics relevant to the SDGs, develop teaching methods that motivate students to think critically and act solutive on global issues, and develop learning evaluations that can measure students' understanding of SDGs issues.

The readiness of teachers PCK is a crucial aspect because not all teachers have adequate competence and experience in integrating the SDGs into learning tools. For this reason, training and professional development for teachers are necessary steps. This training must include an in-depth understanding of the SDGs, innovative teaching strategies, and assessment techniques that support SDGs-based learning. Thus, teachers can be more confident and skilled in designing learning that not only prioritizes academic achievement, but also shapes the character of students with a global perspective.

A number of previous studies have emphasized the importance of Pedagogical Content Knowledge (PCK) as the foundation of teacher professionalism (Shulman, 1986; 1987; Cetin-

Berber & Erdem, 2015). Studies at the local level also show variations in the readiness of prospective teachers in mastering aspects of PCK, both in terms of pedagogy and scientific content (Nuangchalerm, 2020; Tondeur et al., 2017). However, the study generally still focuses only on technology integration or on one particular discipline and not many have conducted a comparative analysis across ASEAN countries. Based on this description, this study aims to analyze the readiness of Pedagogical Content Knowledge (PCK) of prospective science teachers in Indonesia and the Philippines, as well as identify challenges and opportunities for teacher professional development in the context of SDGs implementation.

RESEARCH METHOD

This study will use the research design of the explanatory sequential mixed method. The design of the sequential mixed method of explanation (also called the two-phase model; J. W. Creswell & Clark (2017) consists of first quantitative data collection and then qualitative data collection to help explain or elaborate the quantitative results. The reason for this approach is that the quantitative data and results provide an overview of the research problem; Further analysis, particularly through qualitative data collection, is necessary to refine, expand, or explain the general quantitative picture (Creswell, J., & Guetterman, 2018). The research subjects amounted to 110 prospective science teachers (41 Indonesians, 69 Filipinos) who were selected using purposive sampling techniques. They come from a variety of universities that offer science education programs, with diverse academic year backgrounds and experience in teaching practice. Purposive sampling techniques are used so that participants have adequate knowledge and experience in the context of science education. The questionnaire instrument was developed based on the framework of PCK Shulman (1986; 1987), validated through expert judgment by 2 lecturers of education experts.

The analysis will be carried out in such a way that quantitative research is carried out first and then qualitative research will follow. The quantitative stage is carried out first by distributing the questionnaire online through Google Form, which can be accessed using the account of the respective university institution. Data collection lasted for three weeks. The qualitative stage is carried out after the quantitative results are analyzed. A total of 12 participants (6 from Indonesia and 6 from the Philippines) were selected based on the highest, medium, and lowest readiness categories. Interviews are conducted in a semi structured manner via the Zoom platform in English

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or local languages according to the participants' convenience, with a duration of 30–45 minutes per session. All interviews were recorded and transcribed.

Qualitative analysis was carried out using a thematic analysis approach based on the steps of Braun & Clarke (2006): (1) read the transcript in depth, (2) do initial coding, (3) group the code into themes, (4) review and refine the theme, and (5) interpret the meaning in the context of quantitative results. Data analysis was carried out with SPSS with Independent Sample T-Test for quantitative and manual coding with a thematic matrix for qualitative.

RESULT

Table 1. Level of PK (Pedagogical Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	42	60.9	35	85.4
Moderately Ready	26	37.7	6	14.6
Not Ready	1	1.4	0	0
N=	69	100.0	41	100.0

Table 1 shows that 85.4% of Indonesian students and 60.9% of Filipino students who are prospective science teachers demonstrate readiness in pedagogical skills, while 14.6% of Indonesian and 37.7% of Filipino students are in the fairly ready category, and only 1.4% of Filipino students are categorized as not ready to master pedagogical knowledge. This fairly ready category shows that students have not mastered too many indicators that must be achieved in Pedagogy. The pedagogical knowledge assessed in this study is to see how to assess student performance in the classroom, how to teach, my teaching style for diverse students, how teachers use various teaching approaches, how to overcome student misunderstandings, how to manage the classroom, and how to adapt the learning approach to the student's condition.

Table 2. Level of CK (Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	37	53.6	21	51.2
Moderately Ready	30	43.5	20	48.8
Not Ready	2	2.9	0	0
N=	69	100.0	41	100.0

Table 2 shows that 53.6% of Indonesian and 51.2% of Filipino prospective science teachers are ready in science content knowledge, while 48.8% of Indonesian and 43.5% of Filipino students are fairly ready, and only 2.9% of Filipino students are not ready. This category of quite ready shows that students have not mastered the indicators that must be achieved in science

knowledge material. The knowledge of the content of science material assessed in this study is that students have sufficient knowledge of physics, chemistry, biology. The second indicator is that students can integrate SETS (Science, Environment, Technology, and Society) in classroom learning. The third indicator is that students can match science material with the learning approach they want to use. The fourth indicator is that students can apply contextual learning, namely presenting science in real life. The fifth indicator is that students can apply their knowledge in the fields of Physics, Chemistry, and Biology and slice it into classroom learning. The eighth indicator is that students have extensive knowledge that is currently taught, namely biophysics, biochemistry, environmental balance, plants, animals, global warming.

Table 2 above also explains about students who belong to the unprepared group. There were 2 students from the Philippines while from Indonesia there were no students who were included in the unprepared category. The lack of pedagogy means that students do not know much about what science materials must be taught to students at school. In addition, they also lack understanding of the latest and current material that must be mastered if they want to become science teachers.

Table 3. Level of PCK (Pedagogical Content Knowledge)

Level of Readiness	Philippines		Indonesia	
	F	%	F	%
Ready	31	44.9	24	58.5
Moderately Ready	34	49.3	17	41.5
Not Ready	4	5.8	0	0
N=	69	100.0	41	100.0

Table 3 shows that 44.9% of Indonesian and 58.5% of Filipino prospective science teachers are ready in both pedagogical and content knowledge, while around 41–49% are moderate ready and only 5.8% of Filipinos are not ready. This category of sufficient readiness indicates that students have not mastered the indicators that must be achieved in the PCK assessment. The things assessed in this study include how students choose an effective teaching approach to guide students' thinking and learning on science materials, how to choose different learning models to teach various topics on science materials, and how to choose different learning methods to teach various topics in science materials.

DISCUSSION

The results of the study show that the level of Pedagogical Content Knowledge (PCK) readiness of science teacher candidates in Indonesia and the Philippines is in the medium to high

category. Prospective teachers in Indonesia show the same percentage of PCK readiness as their counterparts in the Philippines. Inferential analysis with the Independent Samples T-Test showed that there was no significant difference (P>0.05) in the aspects of Pedagogical Knowledge (PK) or Content Knowledge (CK). Prospective teachers in both countries have been able to implement pedagogical strategies. The results of qualitative interviews reinforce this interpretation. The main themes that emerged included: (1) the limitations of teaching practice experience in secondary schools that affected pedagogical readiness; (2) the influence of differences in the national curriculum on the structure and depth of science material; and (3) variations in teacher training approaches, especially in the use of technology and the integration of SDGs values. One of the participants from Indonesia emphasized the importance of "learning how to connect science content with environmental and sustainability issues." These findings clarify the contribution of the mixed methods approach. The readiness of the PCK between Indonesia and the Philippines can be explained by several contextual factors. Indonesia has implemented the Teacher Professional Education (PPG) program and the Merdeka Learning curriculum which provides space for prospective teachers to innovate in learning practices. These findings are in line with research by Nuangchalerm (2020) and Prachagool & Nuangchalerm (2019) which shows that PCK readiness in the ASEAN region is strongly influenced by national policies and local curriculum orientation. Research by Forsler et al. (2024) and Zubaidah et al. (2023) confirms that strengthening the collective PCK oriented towards Education for Sustainable Development (ESD) is important to improve the competence of 21st century teachers.

The results of this study are expected to expand the study of cross-country PCK in ASEAN through the lens of the SDGs, showing that the integration between CK, PK, and sustainability values must be adjusted to the social, cultural, and educational policy contexts of each country. The results of this study provide strategic input for universities and teacher education institutions (LPTK). First, teacher education programs need to balance strengthening PK and CK through the integration of cross-disciplinary project-based learning that is relevant to sustainability issues. Second, ASEAN cross-border training for prospective teachers is needed so that there is a good exchange of practices in the implementation of SDGs-based PCK. Third, education policymakers in Indonesia and the Philippines need to strengthen partnerships between teacher training institutions to develop contextual and collaborative Education for Sustainable Development (ESD)-based curriculum. Thus, strengthening the PCK of prospective teachers not

only improves teaching competence, but also forms educators who are able to become agents of change for sustainable development in the ASEAN region.Pedagogical Knowledge (PK) is the knowledge possessed by a teacher about effective learning principles, methods, and strategies. The indicators of Pedagogical Knowledge include several main aspects that include the ability to understand learning theories, design learning, manage classrooms, conduct assessments, and utilize educational technology. Teachers who have a good PK are able to understand how students learn, choose methods that suit their learning needs, and create a classroom environment that is conducive to learning. One of the main indicators is the understanding of prospective teachers about the student learning process. It includes knowledge of cognitive development theories, learning styles, motivations, and diverse learning needs. In addition, the ability to design learning is also an important indicator. Prospective teachers must be able to make a Learning Implementation Plan that is in accordance with the curriculum, choose relevant learning methods, and determine measurable learning goals.

Content knowledge (CK) includes an in-depth understanding of basic concepts in science, the ability to explain scientific phenomena, and the skill of integrating various branches of science such as physics, chemistry, biology, and earth science. CK is very important to ensure that prospective teachers are able to deliver material correctly, accurately, and relevantly. One of the main indicators of CK is mastery of basic concepts in science. Prospective teachers must understand the main principles in science, such as the laws of physics, chemical cycles, the structure and function of living things, and geological processes. This knowledge must be holistic, which means that prospective teachers are able to see the connections between branches of science to provide students with a complete picture of the world of science. Another indicator of a prospective teacher mastering content knowledge is that the teacher can explain and model scientific phenomena clearly and logically. Prospective science teachers must be able to use easy-to-understand language to explain abstract concepts to students. For example, explaining the concept of gravitational force or photosynthesis with concrete examples that are relevant to daily life. This ability also includes the use of visual aids or practicum to clarify explanations.

The readiness of content knowledge can also be assessed from the ability of prospective teachers to relate science knowledge to the context of real life and global issues. For example, prospective teachers must be able to relate science concepts to environmental issues, such as climate change, pollution, or the energy crisis. This indicator shows that prospective teachers not

only understand the theory, but also its relevance to student life and the challenges of the modern world. CK readiness indicators also include reflective abilities and knowledge updates. Science is a field that continues to develop, so prospective teachers must have a commitment to continue learning, keep up with the development of science, and update teaching materials according to new findings. Based on the above, the readiness of prospective science teachers is not only measured by the extent to which they master the material, but also from their ability to teach the material in a relevant, interesting, and contextual way.

Understanding pedagogy or PK is a requirement so that students can choose the right learning strategy to teach the material. Understanding of teaching materials or CK is also a basic requirement so that students are ready to teach various materials that will be given at school according to their level. If PK and CK have not been mastered, what happens is that prospective teachers will always focus on the content and learning materials only and lack pedagogical strategies so that learning becomes boring because there are few student learning activities. Pedagogical Content Knowledge (PCK) is a combination of mastery of material (content knowledge) and the ability to teach it (pedagogical knowledge) effectively. PCK indicators include the ability of prospective teachers to understand the concept of teaching materials in depth, know the best way to deliver the material to students, and recognize the learning challenges faced by students. PCK integrates knowledge about "what is taught" and "how to teach" to make learning more effective and meaningful. The readiness of Pedagogical Content Knowledge of prospective teachers can be reviewed from several main indicators. First, the ability to identify important concepts in teaching materials that are often misconceptions for students. Prospective teachers must understand learning difficulties that may arise and be able to design learning strategies that can overcome these difficulties. Second, the ability to choose learning methods that are in accordance with the material and student needs, for example using experiments, case studies, or project-based approaches for scientific materials such as science. In addition, the mastery of prospective teachers with learning aids, such as educational technology or interactive media, is also an important part of PCK readiness. Another indicator is the ability of prospective teachers to connect teaching materials with the context of students' daily lives. This aims to enable students to understand the relevance of the material they learn to the real world. The readiness of PCK can also be seen from the reflective ability of prospective teachers to evaluate the effectiveness of their teaching strategies and make improvements based on student input or learning outcomes. Thus, prospective teachers

who have PCK readiness are able to teach material accurately, relevantly, and interestingly, while ensuring that students are actively involved in the learning process.

Content knowledge is now an uncertainty because information technology transfers big data excessively to everyone. Excessive material is sometimes not in accordance with the mental development of a student. Students have their own material packages that must be taught according to their age. This content knowledge should be the basic capital for students to be able to teach in schools. This content knowledge includes an understanding of the material, explaining what material will be taught at the beginning of the semester, and what material will be taught afterwards. If students are not ready to understand the material, then further learning will stop. For example, the material that will be taught in the initial class is basic material such as biodiversity and ecosystems, while the advanced material that must be taught is cells, reproductive systems, and genetics. The material should not be reversed from the way it is given to students because the material is a form of continuous learning. Content seems to be outdated and technology has changed.

The relationship between pedagogical knowledge and content knowledge will be explained in more detail on each indicator of pedagogical ability which includes 10 things. An explanation of the indicators of pedagogical knowledge (PK) and their relation to content knowledge or (CK) will be explained as follows.

3.1. Mastery Of Student Character

Teachers' pedagogic competence in Indonesia requires teachers to be able to understand the development of student psychology by looking at their characters. The pedagogical competence of teachers in the Philippines also states that teachers must be able to appreciate the personal growth of students. This means that a teacher must be able to understand the development of student psychology to be able to determine the right learning strategy. The character of students is directly proportional to the learning model used. Student characteristics are very important for educators to know, because this is very important to be used as a reference in formulating learning strategies. For example, students with active characters are compatible with the discovery learning model in photosynthetic materials.

3.2. Understanding Related Learning Theories

A teacher who understands learning theory will understand how to guide learning so that students can easily accept the material. Pedagogical learning in the Philippines requires professional

teachers to understand the importance of mastery of knowledge, content, and its relevance within and throughout the curriculum (Philippine DepEd Order No. 42, 2017). Teachers in Indonesia are also required to master competencies related to understanding learning theories. Learning theory is the foundation of a learning process that leads to the formation of learning conditions. Therefore, the existence of learning theories will provide convenience for teachers in implementing the learning model that will be implemented and will help students in learning (Saefiana et al., 2020). Learning theory will provide an understanding to a teacher about a child's learning style. The right learning style used by a student will make it easier for him to understand the material. A student has a behavioristic learning style, so he will easily understand abstract material. The abstract material, for example, is virus material that will be understood if memorized repeatedly.

3.3. Curriculum Development

A good curriculum is a curriculum that is always developed every year. Curriculum development aims to adapt education to social changes as well as explore previously untouched knowledge (Harmita, D., & Aly, 2023). Curriculum development must be carried out by a teacher to be able to update the curriculum in accordance with technological developments and the development of the times. Teachers in the Philippines under the regulations of the Department of Education of the Republic of the Philippines must understand how to translate the content of the curriculum into learning activities that are relevant to students and based on the principles of effective teaching and learning. This is also in line with what teachers in Indonesia must do, teachers in Indonesia must understand the principles of curriculum development.

3.4. Implementation of Development Activities

Efforts that can be made to improve teacher professionalism are through the adoption of innovation or the development of creativity in the use of educational technology that utilizes the latest communication and information technology to develop teacher professionalism competencies (Zahara et al., 2024). In addition, development activities that must always be followed by teachers are the development of the ability to make learning media, workshops on making evaluation instruments, curriculum development workshops, learning model development workshops, and various types of learning support workshops.

3.5. Utilization of Technology for Learning Media

Learning media is a way to channel trust between teachers and students, trust here means subject matter in which there is a message that must be understood by students, therefore the

selection of learning media is also very important so that the message is conveyed by students. Teachers can convey material optimally through learning media and students can understand the message conveyed by the teacher (Suminar, 2019). Here are some activities that teachers can do in utilizing technology as a learning medium such as online learning, the use of multimedia, the use of social media as a learning resource, e-books and online articles. Online learning includes the use of platforms such as Google Classroom, Zoom, or Microsoft Teams to host online classes, and LMS (Learning Management System).

3.6. Student Potential Development Facilities

Facilities are one of the main means for children to want to learn. The minimum facilities in the school are physics laboratories, chemistry laboratories, biology laboratories, sports fields, wifi, computers, and social studies laboratories. These facilities must exist and be used by teachers to find student potential or develop student potential. Teachers must learn by utilizing various facilities in schools. For example, teachers must make practicum learning in the laboratory, teachers make learning media that ask students to access with computers. The development of students' self-potential carried out by other teachers is by providing intensive guidance to students, providing assistance to students who lack interest and motivation in learning, setting a good example, inviting students to jointly clean the school environment, carrying out spiritual refreshment activities every morning, holding repetitions for new students, holding extracurricular activities, and giving sanctions and reprimands to students (Amaliyah, A., & Rahmat, 2021).

3.7. Communicate effectively, empathetically and politely to students

A good teacher is a teacher who is always friendly and polite to his students. Teachers have 2 characters that must be mastered, namely strict discipline in class and friendly in communicating with students. Teachers must be able to be open and honest, use positive body language, provide space for students to speak, be patient and tolerant. The above methods can be used to build a better relationship between teachers and students. Good communication between students and teachers can create a positive learning environment, and increase learning effectiveness. The teacher's ability to provide the right reward for the success of students makes students better understand the material being taught, in addition to the teacher's activities that communicate enthusiastically and earnestly in learning activities make students more motivated and easily understand the material (Putri, 2020).

3.8 Application and Utilization of Evaluation of Learning Processes and Outcomes

Evaluation of learning processes and outcomes is an important step to ensure the effectiveness of teaching and the achievement of educational goals. Teachers can evaluate learning in 3 ways, namely diagnostic evaluation, formative evaluation, and summative evaluation. Meanwhile, the function of evaluation is to help the process, progress and development of student learning outcomes in a sustainable manner, as well as to be able to find out students' abilities and weaknesses in certain fields of study, as well as to provide information to parents/guardians of students regarding the determination of class promotion or the determination of student graduation (Idrus, 2019).

3.9. Reflective Actions in Improving the Quality of Teaching and Learning

Reflective action is a process in which teachers critically analyze their teaching practices to improve the quality of learning. The results of this reflection can help teachers to find solutions that can be applied to problems in the classroom. It is important for teachers to reflect, because being a reflective person is a real action for redeemed humans. By reflecting, people are aware of their mistakes, and continue to try to find solutions to their problems as concrete actions from themselves who want to change for the better (Manurung & Listiani, 2020).

Teachers must adapt to their learning activities and find the right learning strategies and technology to be used in the delivery of teaching materials (Denby and Holman, 2002).

PCK is a framework that teachers need to have a deep understanding of the pedagogical components and structure of teaching materials. PCK is an important framework that must be known by a teacher, because PCK will always be used in learning activities and related to students' interest in learning and understanding the material (Tondeur et al., 2017). Koehler and Mishra (2019) argue that PCK helps teachers understand and can use this form of knowledge in the teaching and learning process. Teachers need to know what and how they apply learning strategies or models in a unique context in their classrooms.

The development of teachers' abilities towards PCK in ASEAN is influenced by national education policies which include government regulations and teacher competency activities in designing learning. The quality of learning will depend on learning activities, the way the material is delivered, and the way the teacher teaches. The challenge of this PCK can be seen from the suitability of learning strategies with teaching materials. A wise teacher must adapt the learning strategy to the characteristics of the material. However, for teachers who do not understand PCK, they will teach with the aim that the material is only delivered to students without looking at student

activities in learning. Therefore, schools and organizers must have training courses or professional development programs for teachers and prospective teachers, especially professionals in the field of pedagogy and professionals in understanding teaching materials.

A good teacher is a teacher who is willing to develop learning strategies and adjust to the needs of students. Design thinking must be used for instruction-based classroom activities in preparing teachers in PCK. The state needs to set educational management goals by helping teachers know, understand and be able to use PCK in the teaching process (Blau, I. and Shamir-Inbal, 2017). Especially the teacher preparation program or pre-service teachers who are the younger generation in schools, who understand the development of new learning strategies and are enthusiastic about learning innovations in accordance with the demands of the 21st century. PCK's empirical studies of prospective science teachers show that all areas of knowledge show that they understand the integration of pedagogy, technology and bring different methods and ideas into the classroom learning environment. Teacher preparation programs need to pay attention to teacher competencies and embed PCK into the study program. While the nature of learners' learning is changing, teachers must adapt teaching strategies and they can utilize educational technology for effective teaching (Prachagool, V. and Nuangchalerm, 2019).

The Relationship of Pedagogical Content Knowledge (PCK) to Realize Sustainable Development Action

Pedagogical Content Knowledge (PCK) is an educational concept that emphasizes the ability of teachers to integrate content knowledge and pedagogy in a harmonious manner to create effective learning (Siow Heng Loke et al., 2015; Zubaidah et al., 2023)). PCK has a central role in sustainable development action because it can help educators deliver educational materials related to sustainability in a way that is relevant, interesting, and meaningful for students. Teachers who have a strong PCK are able to bridge the gap between sustainability theory and real practice, so that students not only understand the concepts of sustainability, but are also motivated to take real actions in daily life. Based on the table 3, prospective students of Science teachers from the Philippines and Indonesia have a readiness that is very ready and quite ready more than 90%. This suggests that students who have PCK readiness have been considered able to bridge students to understand sustainability concepts and motivate them to take real action in their daily lives.

Education oriented towards sustainable development demands a multidisciplinary approach that combines social, environmental, and economic aspects (Araneo, 2024). Through

PCK, teachers can design learning strategies that combine scientific knowledge, moral values, and practical skills. For example, in learning about climate change, a teacher with a good PCK can integrate scientific data on carbon emissions with discussions of environmental ethics and action-based projects, such as planting trees or reducing the use of plastics. Thus, PCK allows learning not only to be a means of knowledge transfer, but also a process of character formation that supports sustainable development.

PCK is also relevant in building students' critical awareness of global and local issues related to sustainable development. Teachers can use critical pedagogical approaches to help students understand the root causes of sustainability issues, such as social inequality, exploitation of natural resources, and pollution. Through this understanding, students are encouraged to think critically, find creative solutions, and take responsible collective action. PCK allows teachers to facilitate productive and collaborative dialogue in the classroom so that students feel they have an important role to play in sustainable development efforts (Forsler et al., 2024). In addition, PCK supports the development of 21st century skills, such as problem-solving, collaboration, and digital literacy, which are critical in realizing sustainable development (Shafie et al., 2019). In the learning process, teachers can utilize innovative technologies and methods to provide an authentic learning experience (Ramaila & Molwele, 2022). These innovative learning methods, for example, such as project-based learning and problem-based learning, can provide students with real learning experiences to provide meaningful learning. This approach not only increases student engagement, but also helps them understand the complexity of sustainability issues and the importance of cross-sectoral cooperation to address them.

PCK plays a key role in supporting education as a tool of social transformation for sustainable development (Forsler et al., 2024). With a strong PCK, teachers can create relevant, inspiring, and action-based learning, ultimately helping to shape an environmentally conscious, socially responsible, and empowered generation in the face of global challenges. In the long term, investing in the development of PCK for educators is a strategic step to strengthen the education system and achieve a vision of a more equitable, inclusive and sustainable world.

The readiness of prospective science teachers in understanding Pedagogical Content Knowledge (PCK) plays an important role in supporting sustainable development actions. PCK includes not only the ability of prospective teachers to integrate knowledge of teaching materials and pedagogical strategies, but also their ability to convey scientific concepts relevant to

sustainability issues, such as climate change, natural resource conservation, and environmentally friendly technologies. With a strong understanding of PCK, prospective teachers can design contextual, interdisciplinary, and meaningful learning, thereby equipping students with the awareness and skills to contribute to sustainable development. Therefore, improving the PCK competency of prospective science teachers must be a priority in teacher education to create a generation that is able to face global challenges and realize sustainable development goals.

CONCLUSION

This study shows that the readiness of PCK for science teacher candidates in Indonesia and the Philippines is still at a moderate level, with significant variation between countries. This research reflects that 44.9% of Indonesian students and 58.5% of Filipino students who will work as prospective science teachers have pedagogical readiness and content of science materials (PCK). As many as 41.5% of Indonesian students and 49.3% of Filipino students are in the category of being quite ready to know and master pedagogical skills and the content of science materials. The results of this study make a new contribution to the development of cross-border studies related to teacher readiness in the 21st century. The findings of this study have important implications for curriculum design, teacher training module development, and education policies that are in line with SDGs-oriented competencies. The results can serve as a basis for universities and teacher education institutions to strengthen the balance between content knowledge (CK) and pedagogical knowledge (PK).

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