Pedagogical Content Knowledge Components' Integration in Teaching Biology using IBA: Grade 8 Teachers' Case Study

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Though pedagogical content knowledge (PCK) has been investigated in a variety of study fields, its impact has received little attention since the Department of Education imposed the inquiry-based approach (IBA) during the 2016 K-12 implementation. A type of knowledge that is specific to teachers, PCK is based on how teachers connect their pedagogical knowledge to their subject matter knowledge. Through PCK, teachers can create inquiry classrooms that can strengthen students' scientific reasoning and understanding. The PCK components (content, student's understanding, instructional strategies, and assessment) may be integrated into teaching science as IBA is used. This study looks at how teachers use IBA to demonstrate the mentioned PCK components integration as well as determine the impact of the integration. Based on the school's implementation of IBA and other IBA-related activities, a sample of two beginning and two experienced Grade 8 teachers were chosen. Data were evaluated by in-depth PCK analysis and triangulation involving validation through cross-verification using classroom observations, interviews, and other instructional resources. Beginning teachers integrated the various PCK components more frequently than experienced teachers. Integration impact included cognitive activation and students' conceptual understanding improvement. Future studies on PCK components integration, IBA mentoring and continuing professional development programs are recommended.

Keywords: beginning teacher, experienced teacher, inquiry, mentoring, pedagogical content knowledge, triangulation

Introduction

The three areas of science learning (i.e., whenever applicable, comprehending and using scientific information in the local context and in the global context, executing scientific procedures and techniques, and establishing and exemplifying values and attitudes in science) serve as the foundation of the K-12 curriculum. These areas are based on the K-12 Basic Education Curriculum Conceptual Framework which went into effect in 2016 (DepEd, 2003). To support the obtainment of these areas, the framework indicates approaches such as inter/multidisciplinary approach, society/science technology approach, contextual education, issue/problem-based learning, and lastly, IBA. The most popular strategy in the classroom is IBA, which allows learners the opportunity to investigate a problem, search for possible solutions, observe and pose inquiries, validate hypotheses, and maintain imaginative and intuitive thinking (Ucar et al., 2011). In a similar situation, Lameras et al. (2021) argue that IBA welcomes a variety of instructional approaches that support learning philosophies that promote problem-solving, asking questions, knowledge production, and research.

DepEd requires the incorporation of 4As in the teacher's lesson plans across all disciplines. Simbulan (2018) defines the 4As as Activity, Analysis, Abstraction, and Application. The performance of an activity is one method where students build their understanding of the concept being taught in the context of science instruction. The inquiry begins here. In analysis, students are driven to think critically as they respond to the teacher's questions regarding the activity. Abstraction is the manner in which students draw generalizations from what they observe while participating in an activity. In application, the students apply the knowledge learned by sharing their ideas, creating a product or output, participating in activities, doing a case study, and so on. Inquiry instruction is achieved with well-prepared lesson plans incorporating the 4As, however, teachers should have a firm grasp and greater comprehension of PCK (Bueno et al., 2011). Having a good PCK is essential because it empowers teachers to design inquiry-based learning environments that could improve students' comprehension of science or capacity for scientific reasoning (Magnusson et al., 1999). Kartal et al. (2012) claim that teachers' PCK enables them to integrate scientific topic knowledge, inquiry concepts, and pedagogical skills while taking into account the talents and interests of the students.

PCK, conceptualized and popularized by Shulman (1987), is the best way to describe the body of knowledge that teachers possess regarding how to effectively transfer content knowledge into pedagogically effective forms. It is a component of teacher knowledge that focuses on how teachers communicate their command of the subject matter in a way that students may easily comprehend (Wu et al., 2018). According to the same authors, teachers can simply create a learning environment where IBA is a key component of learning with the help of PCK.

Though it is well acknowledged that PCK comprises four connected fundamental components — knowledge bases involving content, instructional strategies, assessment, and student understanding, such integration of the PCK components of beginning and experienced teachers has not yet been investigated (Chick et al., 2006; Sothayapetch et al., 2013; Magnusson et al., 1999; Park & Oliver, 2008). There has not been much research on how those teachers demonstrate the integration of the PCK components (if any) in the unique setting of IBA instruction. Most research has typically focused on only one aspect of PCK and looked at how it relates to other aspects of PCK or how it affects the evolution of teaching practice (Wu & Badger, 2009).

As previously said, there is a critical need for research work that considers the interrelationships among PCK components as they relate to IBA teaching rather than only focusing on the analysis of individual PCK components. Therefore, the aim of this study is to examine how these groups of teachers use the four PCK components in their lesson plans and in their classroom teaching. By providing fresh evidence supporting the PCK components integration and shedding light on crucial teacher education, the objective of this study is to enhance the PCK literature.

Literature Review

The Concept of IBA

IBA is described by Waters and White (2015) as a teaching strategy that blends students' curiosity and the scientific approach. This combination enhances the development of critical thinking skills while learning science. When students run into issues they don't understand, they approach them as inquiring, critical thinkers who study issues, observe, and apply new knowledge. The learners follow the accepted scientific method when they seek answers and obtain a deeper understanding of the new information.

IBA is hands-on and minds-on (Duran & Duran, 2004). In the classroom, scientific instruction must involve students in inquiry-based projects where they work cooperatively with peers and teachers. This is why Colburn (2000) underlines that teachers must be able to choose techniques and activities that take into account students' needs and learning styles in addition to the subject matter of instruction as the IBA is known to be a highly successful method for learning. With IBA, the students are enjoined to participate in conversations, planning, decision-making, and problem-solving. IBA and learning are born out of constructivism, which is a synthesis of Piaget, Vygotsky, and Ausubel's beliefs regarding the intellectual foundations of learning and teaching (Liang & Gabel, 2005). Constructivism emphasizes the use of active thinking to combine previously learned information with knowledge already in existence (Kirschner et al., 2006).

IBA usually involves inquiry-based learning as one approach. The students' involvement in the learning process is the focus of inquiry-based learning. Students are encouraged to learn the content on their own, make inquiries, and exchange ideas rather than rely on the teacher's instruction. Cooperative learning and guided learning are the two types of instruction used in inquiry-based learning. Students learn best by doing, as opposed to memorization of facts and knowledge. They can do this by engaging in inquiries, experiences, and conversations (Grade Power Learning, 2018). Through analysis and challenging questions, inquiry-based learning keeps students eager to learn. It is a method of instruction that promotes students' participation involving learning by experience and solving problems.

Kartal et al. (2012) claim that teachers' PCK is an important aspect of IBA because PCK enables them to integrate an inquiry classroom where there is discussion of scientific topic knowledge, inquiry concepts, and pedagogical skills. In short, teachers can simply create a learning environment where IBA is a key component of learning with the help of PCK.

PCK and IBA

Some authors claim that using IBA can help develop a teacher's PCK. Thus, PCK has a direct relationship with the said approach. Using a variety of qualitative methods, Nuangchalem (2012) examines pre-service teachers' PCK and the findings indicate that the inquiry approach can enhance PCK which can be used for teacher preparation programs. Similarly, Tas and Heywood (2012) share that the use of IBA is crucial for teachers to link and improve their material and pedagogical knowledge. Furthermore, teachers use the inquiry technique to incorporate understanding of inquiry and create PCK (Tambyah, 2008). The author adds that IBA use involves the planning of practical activities that show new, critical understanding of science concepts.

Other case studies also show that PCK and IBA are related. For instance, the case study conducted by Lehane et al. (2014) involving 12 pre-service science teachers from Ireland captures their PCK using Content Representation (CoRe). CoRe is a tool that suggests research questions on how a teacher teaches the content while taking socioeconomic and cultural factors, teaching methods, and strategies into account. In this study, to foster inquiry orientations, CoRe is somewhat modified. Multiple sources of data such as lesson plans, reflections, observations, and interviews are used to evaluate the action of inquiry in the classroom. In the interview, results indicate the influence on the pre-service teachers' thinking on inquiry as well as the influence on their decision to implement inquiry in the classroom. Similarly, the use of the case study method is effective in documenting and assessing the PCK of five experienced high school and college Mexican teachers (Bueno et al., 2011) in relation to IBA use. Just like the previous study, there is modification of the CoRe into "inquiry CoRe" by incorporating a set of seven inquiry activities. Interviews reveal that all teachers employ inquiry to change their students' ways of thinking, primarily through presenting questions. In this study, there is the assumption that the teachers can demonstrate the seven inquiry activities provided. While some of them use research as their primary method of advancing scientific inquiry, others speak of a lack of time. In this study, the method is only limited to interviews and no mention of documents being analyzed is made. Despite a thorough description of the teachers' PCK in relation to IBA being documented, this is one of the weaknesses of the case study method. Similar to this, Chapoo et al.'s (2014) study, which looks at the beliefs and routines that make up a biology teacher's PCK, shows how biased the case study technique is. Through the creation of CoRe, instruction in the classroom, and discussion during the interview, just one participant's PCK is assessed in this study. Although biased, the case study technique can assess the scope and character of her PCK in comparison to the Magnusson et al. model (1999). The results reveal the teacher's comprehension and application of PCK, which assist in teaching and learning science based on constructivism, even though the conclusions may not also be generalized due to its relatively small size. This study assumes that being an experienced teacher, the participant would be able to demonstrate her PCK in the teaching of Biology.

The Concept of PCK

A subcategory of PCK, concerned with how teachers effectively communicate their grasp of the subject matter to the learners, is crucial in determining effective instruction (Borko, 2004; Shulman, 1987). PCK is a combination of specific subject matter knowledge and pedagogical knowledge that is crucial for teachers to acquire. This combination of content and pedagogy offers insight into how specific topics, concerns, or challenges are arranged, portrayed, and tailored to the various interests and aptitudes of students. Teachers can better comprehend what they know, what they should know, and how to improve their knowledge by using PCK. Because it gives teachers pedagogical reasoning based on a particular subject, particular learners, and specific contexts, PCK is thus very important to teaching practice.

Few PCK studies in the Philippines have been documented. Magdara (2013) looks into the biology teachers' PCK and how it related to the students' science process skills in one secondary high school in the Autonomous Region in Muslim Mindanao (ARMM). Results show a correlation between the PCK of teachers and the science process skills of students when tested using the alpha 0.05 level of significance. To improve student accomplishment in terms of conceptual comprehension and problem-solving abilities, Lucenario et al. (2016) look into the efficacy of PCK-Guided Lesson Study (PCKLS) as an intervention. Data analysis reveals a substantial difference between the scientific teacher abilities of the teacher respondents in the PCKLS group and those in the traditional group. In a different field, Moreno and Ballena (2021) investigate the PCK of online Business English teachers to comprehend its significance in Business English education. The findings show that online Business English teachers can define PCK as knowledge of strategizing forming the understanding that Business English is different from General English as well as it is the language in the workplace.

Similar to this, Manila (2020) examines the PCK in music education of public primary teachers in the District of Mariveles, Bataan, for the School Year 2019–2020. When teachers are categorized according to the number of pertinent seminars and training they had attended, the author discovered that the teachers' content expertise in music differs greatly.

The PCK Components

Knowledge bases involving content, instructional strategies, assessment, and student understanding of science are the four PCK components that have received widespread acceptance from scholars in the area of scientific education (Magnusson et al., 1999). It is simple to observe or describe these PCK components in empirical investigations because they are well-defined, and their sub-components are stated. Magnusson's approach has also been the most widely used since its components are easy to use at all levels of education. In addition, Park and Oliver (2008) listed them as (a) understanding the goals of topic teaching, (b) understanding instructional methodologies for teaching certain subjects, (c) understanding students' grasp of particular subjects, and (d) comprehending the curriculum. The PCK concept also includes learning objectives, ideas and/or misconceptions of students, various resources, teaching style, the goal of subject matter knowledge, evaluation of student learning, and forms of representations (Chick, et al., 2006). Finally, the Sothayapetch et al. (2013) PCK model places an emphasis on student thinking, misconceptions, procedural knowledge understanding, resource knowledge, learning goals, classroom technique, purposes of content, student learning evaluation representations, and student understanding of conceptual knowledge.

PCK components often do not work independently of one another; rather they are dynamically intertwined across the entire PCK construct. Additionally, some researchers agree that when all components are cohesively integrated, PCK functions properly (Loughran et al., 2006; Park & Chen 2012; van Driel et al., 2002). This means that with integrated PCK components, content is taught more effectively because PCK plays an important role in classroom instruction.

Empirical Studies on PCK Components Integration

Magnusson et al. (1999) assert the significance of the relationships between PCK's constituent parts. The authors claim that having a thorough understanding of only one element is insufficient for becoming a good teacher. In short, effective teaching is not the separate existence of each of these PCK components, but rather their intersection and proper integration. Interestingly, improving any of these parts will also improve PCK as a whole because of PCK's integrative nature.

Padilla et al. (2008) focus on how teachers with different orientations to science education convey the same material in varied ways as the association between scientific teaching orientation and other PCK components is studied. For example, one participant applies a lesson emphasizing the particle level while working under an atomistic paradigm placing a higher priority on the sub-microscopic level. The study specifically examines several PCK kinds, including various component integration types. Understanding of the instructional technique and knowledge of the goals (teaching content that is all about the solar system and the universe) are synchronized in PCK Type A (use of videos). Another fusion involves the teachers' updated knowledge of students' performance and the teachers' evaluation expertise (information gleaned from exam papers). Finally, results indicate a correlation between knowledge of assessment and understanding of the instructional method. Teachers use the model's material to train students and evaluate the material when an exam is given. On the other hand, results also indicate that Type B PCK shows integrations between knowledge of instructional strategy and knowledge of goals. Additionally, the findings indicate that the teachers perform assessments more effectively the more in-depth information they have on instructional strategies and learners. According to Henze et al. (2008), each form of PCK has a unique component integration and development of the components. Moreover, Friedrichsen et al. (2009) discovered that experienced teachers' PCK contains some integration, in contrast to intern teachers' PCK, which lacks connectedness between components.

In a study by Aydin and Boz, (2013) in determining how two seasoned chemistry teachers who are instructing students on oxidation-reduction processes and electrochemical cells integrate various PCK components, the results of a thorough analysis, enumerative methodology, and constant-comparison approaches show that understanding the components of the instructional strategy and learner is crucial in the integrations. However, the authors also discovered that teachers' ability to shape their instruction is less successful even when they have knowledge of evaluation and curriculum. The authors reason that knowledge of evaluation and curriculum could stand alone and in no way could affect teaching.

Scope and Limitation

Finding empirical studies through direct observation (observing while teaching in the classroom) or indirect observation (analysis of textual material generated from interviews) involving both beginning and experienced high school biology teachers at this time is challenging. It is challenging that two different age groups of teachers who are geographically apart (one group from lower Region IV-A and the other group from upper Region IV-A) are the subjects of the study. There is a need for a comprehensive empirical study into the PCK of these teachers, particularly as it relates to IBA use. It is crucial to look into how these teachers demonstrate the integration of the various PCK components that are used in their classroom instruction. The purpose of this study is, in particular, to address the following research questions:

1. How do beginning and experienced teachers demonstrate the integration of PCK components while teaching cell division and Mendelian genetics using the IBA?
2. What is the impact of integration on the learning process of the students?
3. How effective is the integration of the PCK components in the teaching-learning process in improving the scientific thinking of the learners?

Methodology

Context of the Study and Participants

The site of the study was in two (2) public high schools in Region IV-A (CALABARZON), Philippines, denoted as Schools A and B (to protect their anonymity). The study was conducted from January to March of AY 2018-2019, which was the year's final quarter. School A, located in the upper part of the province, had a student population of 4,266 and an average class size of 60-65. School B, situated in the lower part of the province had a student population of 4,241 and an average class size of 55-60. Class sizes for the two (2) pilot sections in each of the study's schools ranged from 40 to 50 students. In addition, the pilot sections were part of the Science, Technology, and Engineering (STE) program while all the other sections were part of the regular curriculum with a class size of 60-65. School A had nine (9) Grade 8 Science faculty members while School B had eight (8) Grade 8 Science faculty members. In both schools, the majority of the faculty members in the Science Department were female.

A week prior to the research observation session, all teachers drafted their instructional plans (lesson plans), which they submitted to their science head for checking. The learning objectives, required materials, 4As, assessment, and assignment were all included in this instructional plan.

Although the participating schools needed to use the materials (such as models) provided by DepEd, there were instances when the teachers had to provide their own materials in teaching certain topics in Biology. The Learner's Module (LM) or the main textbook for Grade 8 Science, which is designed following the inquiry approach, is composed of four (4) Unit Topics. Each unit contains three (3) to six (6) modules with specific inquiry-based activity or activities per module. It is in Unit 4 (Living Things and Their Environment) where the module on Cellular Reproduction and Genetics is discussed.

All the teachers used the same module, and each school had its own departmental examination long test/summative test. Based on DepEd guidelines, the type of departmental examination depends on the discretion of the school principal, while the giving of short quizzes depends on the discretion of the teachers. Likewise, the teachers had to use the LM for Grade 8 Science; however, DepEd pointed out that there is no prescribed list of teaching strategies that the teachers need to follow since differentiated strategies are always favored. The study involved teachers from two schools who have different expertise, varied number of years of teaching, subjects taught, and number of professional development programs attended. Because females make up the majority of the faculty members in each department, the study's respondents were entirely female. The profile of the teachers is summarized in Table 1.

Table 1

Profile of the Four Teachers

Teacher Characteristics	Ace	Bes	Ces	Des
Course Graduated	BS in Mathematics and Science Teaching, majoring in Biology	BS Agricultural Education, majoring in Animal Science; also earned some units in MA Education, majoring in Educational Management	BS Agricultural Education, majoring in Animal Science; also earned some units in MA Education, majoring in Educational Management	BS Secondary Education specializing in Biological Sciences
School	A	A	B	B
Years of Teaching	3	19	10	3
Science Subjects Taught	Science 8	Science 7 Science 8	Science 8	Science 8
Years of Teaching Experience in Another School	3	1	1	3
Number of Seminars attended for the last 3 years	1	2	5	4

Design of the Study and Case Selection

This study is a multi-case design which involved four (4) Grade 8 Science teachers from two public high schools in Region IV-A, Philippines who were selected for an empirical investigation on their IBA practice through interviews and classroom observations.

The cases were selected based on the following criteria: (a) the school had imposed on the teachers the implementation of IBA as a teaching approach; (b) the school had been offering the Engineering and Science Education Program (ESEP); (c) some of its teachers have been teaching the investigatory project making in which the inquiry approach is applied; and (d) the school had participated in Regional and National Science Fairs, and had been consistent in winning these competitions. A scientific and math-focused curriculum called ESEP was developed for high schools in the Philippines. Project making is science investigatory project making highlighting the inquiry skills of the students. The participants were identified through the help of the science coordinator of the selected school. Each teacher was selected based on years of teaching experience. Two (2) teachers were observed from each of the two selected target schools. One was from the group of teachers with less than 1 year to 5 years of teaching experience (beginning teachers) while the other one was from the group of teachers with more than 5 years of teaching (experienced teachers).

Data Collection and Analysis Procedures

From January until the third week of February 2019, letters were sent to the Schools Division Superintendent, Division Science Supervisor, and School Principal of the schools. From the fourth week of February to the first week of March, the respondents were met, asked to fill out the teacher's profile form, oriented about the study, and had the first interview. Using an interview guide on knowledge of cell division and Mendelian genetics, the teachers were interviewed separately during their vacant periods. The researcher created the interview guide that consisted of open-ended questions about the teachers' knowledge and understanding of the said topics. Initial questions prepared by the researcher were checked by her dissertation adviser after which the final list of questions was checked by two (2) of the researcher's dissertation panel members. The specific questions asked were (a) "Can you describe what you know about cell division? Mendelian genetics?"; (b) "How do you teach these topics?"; (c) "How do you know if the students understand your discussion?"; (d) "How do you measure a student's learning?"; (e) "What other resources will you recommend to the students in order to learn about cell division and Mendelian genetics?"; (f) "How do you support student thinking when teaching about cell division and Mendelian genetics?; (g) "Why is it important for students to learn about these topics?" The first interview lasted for 30 minutes. In the second interview which lasted for 15 minutes, the information collected during the first meeting was validated and some answers which seemed to be confusing were clarified. During the second interview, the participants' responses were clarified. Classroom observations, done for 10 days (covering the same lesson, i.e., cell division and Mendelian genetics) which were video-recorded (with the teachers' consent), matched with what was written in the teachers' lesson plan. The classroom observation was from the second week until the third week of March; the second interview was done in the fourth week.

The interview data, classroom observations, and documents/artifacts (lesson plans, instructional materials) were analyzed through triangulation and cross-case analysis. The data and video were saved in an external drive protected by a strong password. For further protection, multiple copies of these media files were kept in Google Drive which is only accessible to the researcher.

Data Validation

For checking, all the teachers received exact transcripts (in the vernacular) of the interviews along with the interpretations in the form of claims and supporting text. This allowed the participants the chance to validate both the transcription and interpretations. In this strategy, the teachers were asked to read their typed transcripts to determine if the researcher had "accurately described their experience." Any discrepancy that a teacher reported to the researcher was noted and corrected in the final transcript. Moreover, the findings were subjected to peer examination, in which the findings were given to a second reader who is a professor expert in qualitative research, for comments. The second reader had prior experience in case studies and was familiar with the research methodology.

Protocol for the Conduct of the Current Study

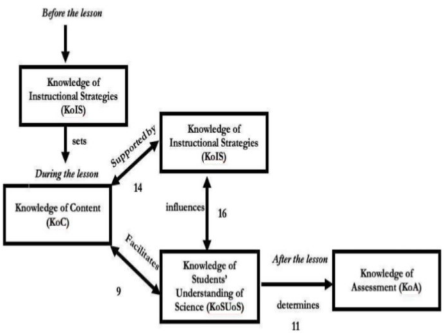
The author's obligations to the participants and to the data collected about them in terms of treating the data confidentially, their voluntary participation in the study, and their right to withdraw at any time were all made explicit in an information sheet. Each participant signed an institutional consent form.

Findings and Discussion

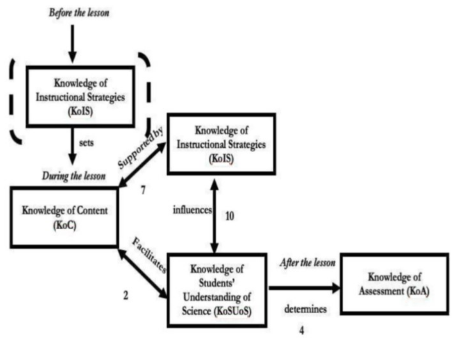
PCK Components Integration: Beginning vs. Experienced Teachers

Figure 1

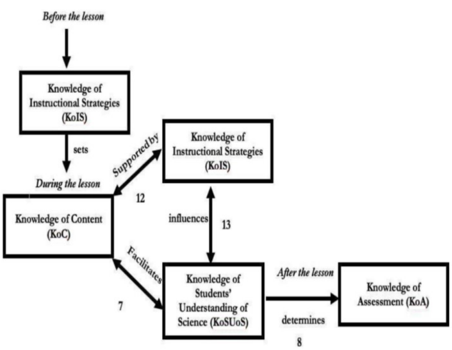
General Pattern of the Teachers' Integration of the PCK Components as IBA was implemented.



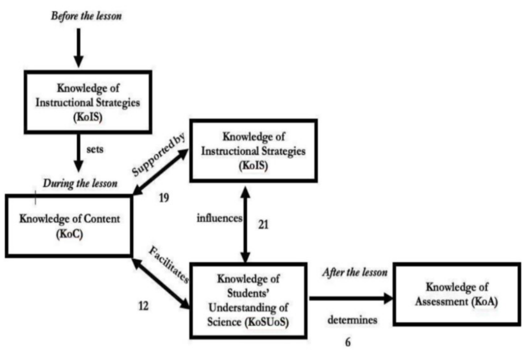
A. PCK Components Integration of T. Ace



B. PCK Components Integration of T. Bes



C. PCK Components Integration of T. Ces



D. PCK Components Integration of T. Des

Note: Numbers indicate the number of frequency of integration observed and broken lines indicate the absence of a motivational activity

Figure 1 shows PCK components integration when the teachers discussed cell division and Mendelian genetics using IBA. The integration of Knowledge of Content (KoC) with Knowledge of Instructional Strategy (KoIS) involved the teaching of content using a specific strategy. The integration happened as the teacher mentioned a concept and right away used a specific instructional strategy to discuss it. For instance, in teaching mitosis, the teachers used a model to discuss it. The KoC-KoSUoS integration involved the teaching of a concept (KoC) that facilitated the students' understanding of the concept (Knowledge of Students' Understanding of Science or KoSUoS). The integration happened during the teachers' discussion of concepts as the students reacted positively (i.e., asked a question to clarify, shared how they learned a new concept, etc.). For example, when DNA was discussed, one student asked a question about its importance. The KoIS and

KoSUoS integration involved the use of different types of instructional strategies (KoIS) (i.e., use of pictures, models, etc., and teaching strategies) that facilitated students' understanding (KoSUoS). The integration happened as types of teaching strategies were used to make the students understand the concepts. For example, employing cooperative learning facilitated the students' understanding of the mitosis stages.

Figure 1 also shows the pattern of how the PCK components were integrated as used in the classroom. As indicated, the three teachers (Ace, Ces, and Des) usually started (before the lesson proper) with a motivational activity (KoIS). This sets the teaching of content. Although Teacher Bes did not use a motivational activity before the lesson (as enclosed by parentheses in broken lines); she instead used a different instructional strategy (lecture-style method) to discuss background information. The teachers proceeded to the lesson proper where they had to teach content (KoC), which was supported by the use of models etc., and/or a specific teaching strategy (KoIS). The teaching of content also facilitated students' understanding (KoSUoS). As noted, KoIS influenced KoSUoS. After the lesson, all the teachers assessed students' learning (Knowledge of Assessment or KoA) as they had to give the students a test or an activity.

Such integrations of the different PCK components as IBA was employed seem to be more effective in teaching the content than without integration of the PCK components. As indicated, this study employs IBA to highlight PCK's integrative character in the classroom and demonstrates how PCK can be developed holistically by focusing on a specific component (Park & Oliver, 2008). Thus, none of the four case teachers used only one PCK component when teaching, and they were more likely to employ a combination of three in one specific area where they were similar. The two components, KoIS and KoSUoS had the highest frequency of integration out of the two combinations (Ace-16, Bes-10, Ces-13, and Des-21). These two PCK components were discovered to operate actively and integrate logically with IBA instruction. This was evident in the way the teachers carefully decided on an inquiry-based technique to use, and as a result, the students were better able to comprehend the topics. The researcher observed the aforementioned situation in the classroom where integration became active. The high frequency of KoIS and KoSUoS integration highlights the significance of consistently incorporating various teaching strategies to teach the subject matter more effectively. As Persaud (2018) claims, instructional strategies act as the foundation of instruction and can aid students in retaining basic information.

The next frequency of integration involved KoC and KoIS (Ace-14, Bes-7, Ces-12, Des-19) given that the discussion's subject matter was supported by a range of instructional strategies. However, all teachers got the lowest frequency of integration for the two components, KoC and KoSUoS (Ace-9, Bes-2, Ces-7, and Des-12). KoA, on the other hand, took a passive role in classroom instruction and showed no synergy with other PCK elements (Ace-11, Bes-4, Ces-8, and Des-6). KoA had no direct bearing on how teachers behaved in class and could neither be learned nor generated through direct observation. The in-depth conversations with the teachers showed that the KoA component, which represents the ultimate assessment of students' academic performance, seems to always stand alone because it is by its very nature an autonomous component.

The next section highlights the findings that show how selected PCK components were integrated into the lessons and differed between beginning and experienced teachers.

KoC-KoIS Integration

It is very important to note that the beginning teachers (Ace-14 and Des-19) showed a higher frequency of demonstrating the KoC-KoIS integration than the experienced teachers (Bes-7 and Ces-12). The higher frequency of integrations shows that the beginning teachers discussed content more thoroughly than the experienced teachers. Moreover, this suggests that by being familiar with a particular teaching method, beginning teachers demonstrated greater content-teaching ability. The beginning teachers, for instance, seemed to be aware that a picture of a chromosome complete with its parts was useful in their discussion. So, as the beginning teachers used a more comprehensive picture, they were able to cover all of the chromosome characteristics including the concept of homologous chromosomes, cell cycle, and mitosis. The experienced teachers, in contrast, only covered a portion of the chromosome due to the simplicity of the picture they presented. Moreover, Teacher Ces focused on the nucleus only while Teacher Bes merely covered some general aspects of the chromosome. Nevertheless, their discussion of the chromosome allowed them to describe the basic concepts of cell division.

To teach the stages of meiosis and characteristics, the beginning teachers seemed to employ better KoIS than the experienced teachers. For the comprehensive discussion on the stages and characteristics of meiosis, the beginning teachers used a video clip, model, visual aid in textual form, and cooperative learning to describe in detail the events that take place in each stage. On the other hand, although she did not cover the prophase 1 substages, Teacher Ces covered practically all of meiosis while Teacher Bes listed only Meiosis II even though she discussed the stages of Meiosis I. Both teachers used a model of meiosis only and this could have limited their discussion. Furthermore, the beginning teachers thoroughly discussed the role of meiosis (i.e., genetic variability, chromosome number reduction, genetic disorder development, and sex cell production) as they used a visual aid in textual form. While Teacher Ces at least acknowledged one role of meiosis, namely that of genetic variability, Teacher Bes did not describe any role. These teachers just merely depended on the lecture-style method, and this did not allow them to explore more about meiosis.

Teaching Mendelian Genetics, a difficult topic, requires teachers to employ a variety of teaching strategies. With a better knowledge of effective teaching strategies to employ, the beginning teachers utilized visual aid in textual form, cooperative learning, and a problem-based method. As they used these strategies, they were able to comprehensively discuss Mendel's experiment and define basic genetic concepts. They thoroughly discussed the laws of heredity, the types of cross, and principle of dominance. While Teacher Bes concentrated solely on the garden peas, Teacher Ces engaged in a question-and-answer session that was quite straightforward. With lecture-style and problem-based methods that these teachers only used, the discussion of content became limited.

KoC-KoSUoS Integration

For the KoC-KoSUoS integration, the beginning teachers also showed more frequency of integration than the experienced teachers (Ace-9, Des-12, Bes-2, Ces-7). This implied that as the beginning teachers knew how to teach the content well, it was expected that the students would understand the concept better. Teacher Ace’s discussion of the concepts of the chromosome, cell cycle, mitosis, meiosis, role of mitosis and meiosis, homologous chromosomes, Mendel’s experiment and the Laws of heredity facilitated students’ understanding. Understanding was achieved as Teacher Ace was able to clarify and elaborate when the students asked questions. For example, when one student asked about the importance of DNA, she described the nature of DNA as the genetic material to make the student understand the concept. To ensure understanding, she asked the student to describe DNA again. On mitosis and its stages, she summarized the characteristics of the chromosomes during mitosis and later challenged the students as she asked them to describe what happens in the last stage. This question facilitated the student’s understanding as two students described that the results are two daughter cells which she acknowledged to be correct.

Meanwhile, when Teachers Bes and Ces used a model of mitosis and meiosis, the students got to understand at least the different stages though the events were not thoroughly discussed. To check understanding, they both asked their students to share their learning for the day. Teacher Ces was also able to facilitate student understanding as she discussed Mendel’s experiment. To verify students’ understanding, Teacher Ces asked a student to solve some word problems in genetics. On the other hand, Teacher Bes’ discussion of Mendel’s experiment focused on garden peas, emphasizing the reason why this plant was chosen as the experimental plant. As the discussion led to solving genetics problems, Teacher Bes provided another problem to check if the students really understood the concept.

KoIS-KoSUoS Integration

Finally, the KoIS-KoSUoS integration (Ace-16, Des-21, Bes-10, and Ces-13), implied that the beginning teachers' knowledge of what specific teaching strategy to employ dictated the students' ability to understand the concepts.

In the KoIS-KoSUoS integration, the beginning teachers (Ace-16 and Des-21) were also found to have a higher frequency of demonstrating the integration of these PCK components than the experienced teachers (Bes-10 and Ces-13). Integration of KoIS and KoSUoS was demonstrated better by the beginning teachers than the experienced teachers. Students' understanding was observed as the teachers encouraged them to inquire or to describe the previous concepts discussed or learned using a specific teaching strategy. For example, after discussing the chromosome using a picture, Teachers Ace and Des asked one student to describe it again based on the previous discussion. Understanding the chromosome made the students learn about the DNA, homologous chromosomes, and cell cycle, using a model, visual aid in textual form, and cooperative learning. In cooperative learning, the beginning teachers used mitosis and meiosis models to facilitate students' understanding of the characteristics of each stage. To make sure that the students had a clear understanding, they asked a volunteer to discuss what they learned from the discussion as the model was used again. On the other hand, Teachers Bes and Ces used a model of mitosis and meiosis, visual aid in textual form on the role of meiosis and lecture style method about the other topics. Though exhibiting KoIS, the discussion of the aforementioned topics seemed to be incomplete. Nevertheless, they both checked students' understanding as they asked the students about what they learned for the day. Teacher Ces, on the other hand, engaged in a clear question-and-answer session about Mendel's experiment while Teacher Bes completely focused on the garden peas. The discussion of the subject matter became constrained since these lecturers exclusively used the lecture-style method and the problem-based method. Nevertheless, students' understanding was achieved as the students were asked by both teachers to solve a genetics problem.

Impact of the Integration on the Learning Process of Students

The interactions of the PCK components have a direct impact on how well inquiry teaching works (Abell, 2008; Shulman, 1987). In other words, the consistency of the interactions between the components and a teacher's PCK level are interdependent (Friedrichsen et al., 2009). In this study, the integration of PCK components established a more supportive learning environment among the students. For instance, Teacher Ace's integration of media (KoIS) for students' understanding of cell division (KoSUoS), offered immediate engagement. As observed, the learning environment supported the students to pay attention and stay interested in the concepts being discussed. In this environment, the students participated actively as they asked questions and contributed their ideas to the class. Similarly, Teacher Ces' use of video animation of mitosis (KoIS) for students' understanding of cell division (KoSUoS) encouraged engagement and created an active learning environment. As observed, they were very excited as they shouted "wow, excellent, amazing" with eyes wide open. They were not only attracted to the colors and movement of the chromosomes, but they were also thinking of the process. The visual nature of the video appealed to the students, allowing them to process information. In another instance, when Teacher Bes showed the stages of mitosis (KoC) in the Smart TV (KoIS), it created a learning environment for the students as they sat together in one area and excitedly watched the video. As Teacher Bes gave the instructions, the students actively participated by discussing and analyzing the video being shown. Similar to this, in one classroom activity of Teacher Des, a shift from a passive to an active environment occurred when the teacher showed a brief video clip on the DNA (KoC). As observed, the students engaged in conversation about the video.

Specifically, this integration revealed a significant correlation with students' cognitive activation. Cognitive student activation refers to the process of stimulating students' minds to conduct an in-depth analysis of the subject matter while they are learning (Grob-Mlynek et al., 2022). Descriptive studies are limited to inferring information about a subject's cognitive activity through observed attitudes such as students' verbalizations. These include the verbalizations that students use to explain their problem-solving procedures, engage in argumentation, mention the contributions of other students, draw on knowledge previously learned, apply learning to new situations, form wise guesses and assertions, inquire on the topic at hand, make differentiations, and make judgment. As observed, the teachers' use of instructional materials (KoIS) such as mitosis and meiosis models, videos, and Smart TV to show cell division, pictures of the cell cycle, cell division, chromosomes, DNA, etc. allowed them to pose more questions on a cognitive level, which can be, or in fact are, answered by their students, thus activating their understanding (KoSUoS). Students participated in cognitive activity by posing questions to one another or gaining knowledge from group members' discussions. For example, when the students had a group discussion/cooperative learning about the stages of mitosis, there was an exchange of ideas where the students helped one another in learning concepts. The students' discussion helped the group to decide on what they would submit as an output. By helping one another, they were able to come up with a good output based on the concepts they learned from the group discussion. This is consistent with what Hamann et al. (2010) had reported, that a group of students can continue to learn new things from one another. Working in a group helps students become more productive, being able to produce a comprehensive output, increasing their productivity (Reddy, 2019). When working in a group, everyone cooperates and utilizes their best abilities to produce high-quality results. Moreover, with a group, each member has the chance to present their own thoughts and ideas, opening up new ways to finish the task properly (Jaques, 2003). Likewise, in the group discussion/ cooperative learning involving solving genetics problems, students' cognitive activation was observed as the students explained their problem-solving procedures as well as made comparisons of their answers with those of the others. Grantham (2008) opined that while working in a group, everyone gets high cognitive activation as the students were given the freedom to interact effectively within the group. Because of this, there was easy and smooth communication among the group members in this study, which greatly aided in the success to come up with the best solution to the genetics problems.

Moreover, the integration of the PCK components showed an impact on students' improvement of conceptual understanding. As observed, the concept of cell division and Mendelian genetics (KoC) was explained completely using models, multimedia materials, and forms of representations (KoIS). For instance, when Teachers Ace and Des used models and multimedia materials to explain/define terms/concepts in cell division and Mendelian genetics, the students' conceptual knowledge improved as they confidently repeated the description of the concepts in their own words. Along with using the instructional materials, the students learned how to group information into a sound scientific concept. In another instance, when the students had a group discussion in Teachers Bes and Ces' classes, they were able to chronologically arrange the events that take place in each stage using the mitotic model. Tang and Intai (2017) emphasize that as teachers present visuals, resource materials, pictorial representations, or problems of some sort, the students build an understanding of scientific concepts. Similarly, the step-by-step procedure of solving genetics problems was well understood by the students as illustrations and diagrams were used by the teachers for more effective instruction. O'Dwyer et al. (2015) report that with PCK components' integration, students improve conceptual understanding as they were given opportunities to apply their learning about a particular biology lesson.

Effective Integration of the PCK Components in Improving the Students' Scientific Thinking

The effectiveness of the integrated PCK components was observed in the way the students asked questions showing an improvement in their critical and problem-solving skills. According to Chin and Osborne (2008), questions from students show that they are thinking critically. In this study, the following was observed. When Teacher Ace implemented the motivational activity on taking a bath, one student was motivated to ask the question, "Is there a scientific explanation for taking a bath?" Teacher Ace attended to the student's critical mind as she replied, "removing dead cells when taking a bath means that our cells divide." In another instance, after seeing a video about the chromosome, one student of Teacher Des participated actively as he asked, "Ma'am, how important are the chromosomes?" and she answered this by showing a picture. In Teacher Ces' class, one student was so engaged while examining the chromosomes under the microscope as he asked, "Ma'am, why are the chromosomes colored? What makes them colored?" These are questions of curiosity, which made Teacher Ces explain that "it's due to the staining solution used to color the chromosomes to make them visible and evident." The student continued, "So Ma'am, we cannot use just any dye to color the chromosomes?" Teacher Ces said, "Yes because there are specific staining solutions that can only be absorbed by the chromosomes."

When the students composed their questions, there was reflective thinking as well as inquisitiveness and curiosity (Minigan, 2017). Reflective thinking, which especially refers to the procedures of examining and passing judgment on what has transpired, is a component of the critical thinking process (Minigan, 2017). For instance, when the students discussed quite loudly the answers to the guide questions, there was the assumption that the students imagined themselves taking the roles of these organelles allowing them to analyze and make judgments (Porntaweekul et al., 2013). In her classroom, Teacher Ces used a story-telling approach in discussing the functions of the different cell organelles. The story is about the complaint of a group of organelles as "company workers" (mitochondria, lysosomes, ribosomes, Golgi bodies, and endoplasmic reticulum) who claimed that while their work is very tiring and routinary, the work of the other group of organelles (cell membrane, cell wall, and chloroplast) is very light. To clarify the complaint, in an emergency meeting, the nucleus as the "head of the company" gives the workers a chance to defend their side. She divided her class into small groups where she distributed a copy of the story and told them to discuss based on the guide questions. As the students finished reading the story, two students took turns in asking the questions, "Can I be an organelle?"; "Is it possible to have more than two functions?"; "What will happen if this is so?"; "How do we differentiate between a chloroplast and a mitochondrion?"; "Can we become a chloroplast? Mitochondria?" Teacher Ces' use of this instructional strategy integrated with students' understanding made the students more inquisitive. In another instance, Teacher Ace did not show a video due to time constraints. Nevertheless, a video clip on fertilization was shown outside her regular class which the researcher was able to observe. After her video presentation, the students were stimulated to think as they raised their hands to clarify their thoughts. One student's question was, "What if the cell does not pass the cell cycle, will there be mitosis or meiosis?" The video presentation as a strategy integrated with students' understanding of content making the students more curious. According to Wright et al. (2015, p. 65), "learners become critical thinkers when they master certain skills such as the ability to clarify." Finally, when Teachers Bes and Des asked the students to solve genetic problems, the students were motivated to think reflectively as they moved their heads up and down and immediately asked the questions, "How do we report the genotypic and phenotypic ratios?" and "How do we differentiate between solving a problem involving monohybrid and dihybrid crosses?" Such questions were answered completely by the teachers as they showed examples on the board.

Conclusions, Implications, and Recommendations

The study looked at how four Filipino high school female science teachers integrated the PCK components into their actual classrooms. The integration involved KoC and KoIS, KoC and KoSUoS, and KoIS and KoSUoS. There was no observed integration between KoC and KoA. As observed, assessment was implemented when the students took a test about their learning of the concept/s taught by the teachers. Knowledge of assessment stood alone. Students' understanding of content was supported by the teacher's use of a variety of instructional strategies. Cognition activation and improvement of conceptual understanding were found to be the impact of PCK components integration on the students' learning process. With the integrated PCK components, the students were found to improve scientific thinking as they learned to formulate and ask their own questions.

Developing scientific thinking in students is typically the goal of science education. The concept of conceptual understanding development or knowledge development is already present in the teaching of science concepts. IBA is currently one of the emphasis areas for knowledge construction in the Science Curriculum Guide for the K-12 Basic Education Program; hence, the constructivism principle supports the idea. Different strategies (i.e., designing own experiment, debating on science issues, case studies, group reports, unique activities like rotation brainstorming, standing by your quote, identifying the unknown, etc.) may be used in this situation under the umbrella of IBA. To make the teaching of Grade 8 biology students effective, it is crucial to take into account the idea of integrating the PCK components into IBA.

The results of this case study imply that science teachers should be conscious of integrating the PCK components to better influence their teaching behavior and performance. Both beginning and experienced teachers should be asked to record their teaching and student conduct to keep an eye on their own teaching. Recording may be done by colleagues once in a while. This way, despite their busy schedule, they can still reflect on how the PCK components perform and are integrated into their classroom teaching techniques. Self-reflection and observation may help teachers better comprehend the functions of the PCK components when integrated to improve their instructional practices.

High school science teachers may be offered professional development seminars, courses, and workshops on how to integrate PCK components as well as increase their understanding of these components in IBA teaching. Further recommended are future studies on PCK and IBA across science grade levels and mentoring on IBA and PCK components integration.

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