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A Study of Teachers' Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) and its effects on the Students' Conceptual Understanding in Biology at Secondary School level of Sukkur Region.

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Abstract
This study perceives for the role of teachers' Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) to enhance the students' conceptual understanding of biology at the secondary school level in the Sukkur region. Mixed-methods approach was applied, collected data were analyzed through surveys, achievement tests (mcqs), and semi-structured interviews with teachers, students, and headmasters respectively. The findings of this study express that teachers with strong CK effectively deliver subject-specific knowledge, while those with vigorous PCK employ various instructional strategies through which student engagement and comprehension were improved. Though, many challenges hinder the actual implementation of CK and PCK, including teacher resistance, content knowledge gaps, financial constraints, infrastructure limitations, and a lack of scientific incorporation due to inadequate training and rigid curricular structures. Furthermore, external pressures from parents and students reinforce traditional teaching methods, limiting pedagogical innovation. This study highlights the essential need for targeted professional development programs, enhanced resource allocation, and policy reforms to support the incorporation of CK and PCK in biology education. These challenges are addressing the essential for development high-quality biology education for improving and enlightening students' scientific knowledge.

Introduction
Biology is the scientific study of living creatures and their interactions with the environment. It explores the structure, function, growth, evolution, distribution, and taxonomy of all living things, from the simplest bacteria to complex ecosystems. Biology is important for understanding the natural world and addressing various global challenges, such as: health and medicine, innovation and biotechnology, climate change, environmental conservation, pandemics, food production and security, (Campbell & Reece, 2008). The importance of biology lies in its ability to provide insights into the complex relationships between living organisms and their environment, enabling us to develop innovative solutions to these challenges. Biology education offers numerous benefits for students, including the development of critical thinking and problem-solving skills (National Research Council, 2012), fostering of curiosity and appreciation for nature, promoting interdisciplinary learning, hands-on learning experiences, real-world applications (American Institute of Biological Sciences, 2019), preparation for careers in science (Bureau of Labor

Statistics, 2020), development of scientific literacy healthcare (Centers for Disease Control and Prevention, 2019), and conservation, and enhancement of understanding of human health and well-being (National Research Council, 2012). Moreover, biology education can improve students' scientific literacy, enabling them to make informed decisions about personal health, environmental issues, and technological advancements (American Institute of Biological Sciences, 2019).

Biology is a compulsory subject in almost all grades in all school types particularly at secondary school level. It is a science subject and must be taught along with the practical and technological activities. Biological sciences are educated in Pakistani schools under the title of natural sciences at secondary school level. It is taught in schools as a major subject from secondary level to degree level. However, from class six to class eight it is taught under the title of general science (National Academy of Sciences, 2019). Practically all the universities are presented the subject at advance level. Biology is the key science subject particularly in medical science. This biology subject matter knowledge is often developed over many years with a focus on personal learning and construction of how that subject is known (American Association for the Advancement of Science, 2019).

Content Knowledge (CK)

However, teacher's content knowledge (CK) leads to knowledge or specificity of disciplines or subject matter. CK is different at each level in Primary, Secondary and Higher Secondary Schools. A biology science teacher is expected to master this knowledge to teach. CK is also important because it determines the specificity of thinking from certain disciplines in each study. Teacher's Content Knowledge (CK) refers to the knowledge and understanding that teachers possess about the subject matter they teach (Shulman, 1987). CK includes knowledge of the concepts, principles, theories, and practices within a particular discipline or subject area. Teachers must possess a deep understanding of the content they are teaching in order to effectively use knowledge to help students understand and master the material. CK is essential for student learning and understanding because it enables teachers to design effective lessons, to ask informed questions, to assess student learning and to provide accurate and clear explanations.

Teachers with CK can design lessons and assess student learning effectively, identifying areas where students need additional support (Ball, D. L., Thames, M. H., & Phelps, G. 2008). Teachers with CK can provide accurate and clear explanations of complex concepts, helping students to understand and learn. This includes an understanding of the content's structure, key concepts, and the ability to explain and apply the content knowledge to the use of skills in the classroom Malik, Rohendi, & Widiaty, (2019). Teachers with CK can inform the design of the curriculum, ensuring that it is aligned with the subject matter and meets the needs of students. Teachers with CK can make informed instructional decisions, selecting teaching strategies and resources that are aligned with the curriculum. Teachers with CK can support student learning, providing scaffolding and feedback that helps students to meet the learning objectives.

The benefits of teacher's content knowledge CK for students include:

1. Deeper understanding: Students taught by teachers with CK are more likely to develop a deeper understanding of the subject matter.
2. Improved academic achievement: Students taught by teachers with CK tend to perform better academically.
3. Increased motivation: Students taught by teachers with CK are more likely to be motivated and engaged in learning.
4. Better preparation for future studies: Students taught by teachers with CK are better prepared for future studies and careers (Ball, D. L., Thames, M. H., & Phelps, G. 2008).

Pedagogical Content Knowledge (PCK)

Pedagogical Content Knowledge (PCK) describes the general goal of the specificity of knowledge to teach. It is a collection of skills that the biology science teacher must develop in order to be able to manage and organize teaching and learning activities to achieve the expected learning goals. This knowledge includes understanding classroom management activities, the role of student motivation, lesson plans, and learning assessment. PCK also describes the knowledge of different teaching methods including knowledge to know how to organize activities in the classroom so that the construction of student knowledge is helpful (Koehler and Mishra, 2013).

Pedagogical Content Knowledge (PCK) referring to the statement of Abbitt, J. T. (2011) is that an effective teaching requires more than just a separation of understanding of content and pedagogy. PCK also recognizes the fact that different content will match different teaching methods. For example, speaking skills in biology is more appropriate with a student-centered approach so that learning is more meaningful. Unlike the lectures on art appreciation seminars, it is more appropriate to use teacher centered. PCK has a meaning beyond just content experts or know general pedagogical guidelines, but more about understanding of the mutual influences between content and pedagogy. Teachers must also possess an understanding of effective teaching strategies and the ability to apply these strategies to the use of knowledge in their instruction (Morine-Dershimer and Kent, 1999). According to Abell, S. K. (2007), PCK includes knowledge of:

1. Curriculum materials: Teachers' knowledge of textbooks, educational software, and other curriculum materials.
2. Teaching strategies: Teachers' knowledge of instructional methods, such as lectures, discussions, and hands-on activities.
3. Assessment methods: Teachers' knowledge of how to assess student learning, including quizzes, tests, and project-based evaluations.
4. Student learning difficulties: Teachers' knowledge of common misconceptions and difficulties that students may encounter when learning specific content.

Objectives

1. To explore the effect of teachers' Content Knowledge (CK) on students' conceptual understanding in biology.
2. To assess the effects of Teachers' Pedagogical Content Knowledge (PCK) on students' conceptual understanding in biology.
3. To assess the student’s conceptual understanding in biology.
4. To investigate the Problems faced by HMs remain cooperating CK and PCK.

Research Questions

Q1. What are the effects of Teachers’ Content Knowledge (CK) on the students’ conceptual understanding in biology?

Q2. What are the effects of Teachers’ Pedagogical Content Knowledge (PCK) on the students’ conceptual understanding in biology?

Q3. How do you assess the students conceptual understanding in biology?

Q4. What are the Problems faced by HMs remain cooperating CK and PCK?

Literature Review

Content knowledge is knowledge of the subject matter. This is subject-specific; for example, science content is different from art content. Content knowledge is the body of knowledge from the field. Subject matter experts have a wealth of content knowledge but may lack the pedagogical or pedagogical content knowledge to effectively teach what they know (Voogt, et al, 2016). Shulman (1986) notes that concepts, theories, organizational frameworks, and field-specific practices for developing knowledge all fall under the supervision of content knowledge. Knowledge and approaches to inquiry are field-specific, and content knowledge is an important foundation for biology teachers to develop (Mishra and Koehler, 2008).

Pedagogical knowledge comprises a general conception of how students learn. This includes knowledge of social, cognitive and developmental learning theory and an understanding of educational goals, values, strategies and intents. PK involves strategies and methods for classroom management, lesson planning, assessment and evaluation as well as comprehension of how learners construct knowledge and develop dispositions toward learning (Harris et al., 2009). Morine-Dershimer and Kent (1999) describe three types of pedagogical knowledge, including general pedagogical knowledge, personal pedagogical knowledge and context specific pedagogical knowledge. General PK includes knowledge of strategies for instruction, models of instruction, classroom management, classroom organization and classroom communication and discourse. Personal PK is informed by personal beliefs and perceptions as well as practical experience. Both general and personal PK, when combined with reflection, yield context specific pedagogical knowledge (Voogt et al, 2013).

Pedagogical content knowledge refers to the understanding of how certain subject matter can be optimally organized and communicated for diverse learners; PCK, as Shulman (1987) asserts, is a distinguishing characteristic between educators in particular content areas and content experts (Shulman, 1987). For example, scientists may possess a wealth of content knowledge but lack the pedagogical content knowledge required to be effective science educators. PCK was originally explained by Shulman to include two components: knowledge of ‘representations’, which include instructional strategies, explanations, representations and demonstrations that educators use to help present and clarify content for learners; and knowledge of students’ ‘learning difficulties’, which encompasses misconception, disinterest or any other barriers to learning which may have resulted from prior experience with a particular topic and how to appropriately address correcting misconception and scaffold further learning of this subject matter Masrifah, et al, (2018).

Shulman’s model of PCK has been utilized and developed throughout the literature since its initial conception (McCaughtry and teaching, 2005) contends that while Shulman (Shulman, 1987)’s (1987) model of PCK is a valuable construct for understanding the integration of teachers’ knowledge of subject matter, pedagogy, curriculum, and learning processes as a unique form of knowledge in and of itself, it neglects related knowledge types upon which teachers draw to inform their teaching. All of these, in combination with knowledge of educational context, are enveloped by pedagogical content knowledge (Voogt, et al, 2016). In further organizing PCK, (Veal et al., 1999) classify levels of PCK in a hierarchical taxonomy. This includes general PCK, which is pedagogical knowledge related to the general content area (e.g., science), domain specific PCK, which is pedagogy related to a particular subject within the content area (e.g., biology), and topic specific PCK, which includes knowledge pertinent to teaching the specific concepts within the content area (e.g., cellular mitosis).

Method

The research design used in this study was descriptive in nature. Mixed methods (quantitative and qualitative) were adopted for analysis of data in this study research work (Clark & Creswell 2008).

Population

The population of the study was contained of:

- All the teachers of government Secondary school levels (IX class) of Sukkur Region.
- All the students of government Secondary school levels (IX class) of Sukkur Region.

- All the headmasters of government secondary school levels of Sukkur Region.

Sample Size

The sample size for quantitative data of this research was calculated by using Taro Yamane (Yamane, 1967) formula with 95% confidence level. From the total population of (Students=29669, n=198 sample was collected), from total population of (Teachers=179, n=124 sample was collected) and it was selected by stratified random sampling method. The sample size for qualitative data of this research was collected 10 interviews from headmasters and it was selected purposive sampling technique (Creswell & Plano-Clark, 2013).

Research Instruments

- Questionnaire for Biology Teachers (Five-point Likert scale 5.0) of IX class of government Secondary Schools.
- Achievement test (MCQs) for Biology Students of Ix class of government Secondary Schools.
- Semi-structured Interview for headmasters of government Secondary Schools

Reliability of The Research Instruments

Components	Cronbach's Alpha
CK	0.867
PCK	0.897
Student's Achievement Test	0.864

Data Analysis and Interpretation

Objective one

To explore the effect of teachers' Content Knowledge (CK) on students' conceptual understanding in biology.

Table No: 2. Overall Mean Score OF CONTENT KNOWLEDGE (CK)

Item code	Content Knowledge	Mean	SD	Decision
01	Teacher delivers the relevant knowledge of biology.	4.35	0.625	High Extent
02	Teacher considers objectives in the curriculum of the biology subject.	3.73	0.94	High Extent
03	Teacher assigns students to learn topics through experiments in biology subject.	3.71	1.002	Moderate
04	Teacher has various ways and strategies of developing his understanding of biology subjects.	3.98	0.576	High Extent
05	Teacher utilizes library for teaching and learning biology.	3.4	1.011	Moderate
	Total Mean Score	**3.83**	**0.83**	**High Extent**

Result:

- The table indicates that teachers' Content Knowledge (CK) significantly impacts students' conceptual understanding in biology, with a total mean score of 3.83 and a total standard deviation of 0.83. Teachers demonstrate a high extent of CK in delivering relevant knowledge (M = 4.35, SD = 0.625), aligning lessons with curriculum objectives (M = 3.73, SD = 0.94), and employing diverse strategies (M = 3.98, SD = 0.576).
- However, experimental learning (M = 3.71, SD = 1.002) and library utilization (M = 3.4, SD = 1.011) received moderate ratings, indicating areas for improvement. Strengthening

hands-on learning and resource use could further enhance students' conceptual understanding of biology.

Objective Two

To assess the effects of Teachers' Pedagogical Content Knowledge (PCK) on students' conceptual understanding in biology.

Table No: 3. Overall Mean Score OF PEDAGOGICAL CONTENT KNOWLEDGE (PCK)

Item code	Pedagogical Content Knowledge	Mean	SD	Decision
06	Teacher selects effective teaching approaches to guide student thinking and learning in biology.	3.86	0.629	High Extent
07	Teacher creates appropriate lesson plans that scaffold to student learning.	3.81	0.659	High Extent
08	Teacher adopts teaching methodology according to the text book of biology.	3.56	0.913	High Extent
09	Teacher assesses the students during different activities in biology subject.	43.87	0.836	High Extent
10	Teacher assesses the students through time bound assignments in biology class.	3.61	1.018	High Extent
11	Teacher uses a wide range of teaching approaches in a biology classroom setting.	3.81	0.659	High Extent
	Total Mean Score	**3.92**	**0.79**	**High Extent**

Result:

- The table presents the effects of teachers' Pedagogical Content Knowledge (PCK) on students' conceptual understanding in biology, with a total mean score of 3.92 and a total standard deviation of 0.79, indicating a high extent. Teachers effectively select appropriate teaching approaches (M = 3.86, SD = 0.629) and create structured lesson plans (M = 3.81, SD = 0.659) to support student learning.
- They also adopt textbook-based methodologies (M = 3.56, SD = 0.913) and use diverse assessment strategies, including activity-based assessments (M = 3.87, SD = 0.836) and time-bound assignments (M = 3.61, SD = 1.018). Additionally, they incorporate a variety of teaching methods in the classroom (**M = 3.81, SD = 0.659**). Overall, teachers demonstrate strong pedagogical content knowledge, which positively influences students' conceptual understanding in biology.

Objective Three

To assess the students conceptual understanding in biology.

Table No: 4. Overall Mean Score OF STUDENTS' ACHIEVEMENT TEST

Item code	Multiple Choice Question (MCQs)	Mean	SD	Decision
01	Why do different species have a different number of chromosomes?	0.4	0.491	Moderate
02	What is the main purpose of photosynthesis in plants?	0.71	0.456	High Extent
03	How do animals help plants in photosynthesis?	0.82	0.328	High Extent
04	Which statement about bacteria is correct?	0.87	0.339	High Extent
05	What is the role of DNA in a cell?	0.8	0.403	High Extent
	Total Mean Score	**0.72**	**0.403**	**High Extent**

Result:

- The table presents the results of students' achievement test (MCQs) in biology, with a total mean score of 0.72 and a total standard deviation of 0.403, indicating a generally high extent of conceptual understanding.
- Students demonstrated the lowest comprehension in the question about why different species have different chromosome numbers (M = 0.4, SD = 0.491), showing a moderate level of understanding. In contrast, the highest comprehension was observed in the question about bacteria (M = 0.87, SD = 0.339), reflecting a high extent of understanding.
- Similarly, students showed a strong grasp of concepts related to photosynthesis (M = 0.71, SD = 0.456), the role of animals in photosynthesis (M = 0.82, SD = 0.328), and the function of DNA in a cell (M = 0.8, SD = 0.403), all categorized as a high extent of understanding. Overall, the results indicate that students generally have a solid conceptual understanding of biology, with minor gaps in specific topics that may require additional instructional support.

Objective Four

To investigate the Problems faced by HMs remain cooperating CK and PCK.

Semi Structured Interviews For Headmasters

The interviews were conducted from the ten headmasters from Sukkur. The interviews were analyzed through the narrative method. According to the Cresswell (2013) narrative style in qualitative data means / refers such activity in which researcher describe interview result narratively.

Q1. How do you think CK and PCK can benefit teachers and students in your school?

The results for question 1 show that majority of the headmasters answered through enhanced teaching practices and methods and improved student learning outcomes and few headmasters told through better preparation for subject knowledge.

Q2. What challenges have you faced in implementing CK and PCK in your school?

The results for question 2 show that majority of the headmasters have faced challenges like teacher resistance, infrastructure limitations, funding constraints Some teachers were hesitant to adopt new technologies and pedagogies. We faced limited budget for technology and professional development, whereas few headmasters have faced challenges like Content knowledge gaps and time constraints, some teachers lacked content knowledge in specific subjects.

Q3. What barriers do teachers in your school face in integrating technology into their teaching practices?

The results for question 3 show that majority of the headmasters answered that teachers face barriers like Lack of technical skills, Curriculum constraints, Parental and student expectations Some teachers struggle with basic expertise skills, whereas few headmasters answered that teachers face barriers like fear of failure of using new methods, Teachers may face pressure from parents and students to maintain traditional teaching methods.

Major findings of objective one

Content knowledge

The findings for Content Knowledge (CK) indicate that biology teachers exhibit strong subject mastery and effective instructional practices, with high effectiveness in delivering relevant biological knowledge (mean score: 4.35) and aligning lessons with curriculum objectives (mean score: 3.73). Inquiry-based learning is generally supported (mean score: 3.71), though some challenges, such as resource limitations, may hinder consistent implementation. Teachers actively engage in professional development to enhance their understanding (mean score: 3.96), demonstrating a commitment to continuous improvement. However, the use of library resources for teaching received the lowest endorsement (mean score: 3.4), suggesting a need for better access and integration. While overall performance is strong, improvements in experimental learning and resource utilization could further enhance biology instruction.

Major findings of objective two

Pedagogical content knowledge (pck)

The findings indicate that biology teachers demonstrate strong Pedagogical Content Knowledge (PCK), effectively designing and implementing instructional strategies that promote student engagement and understanding. They excel in selecting effective teaching approaches (mean score: 3.86) and creating lesson plans that support student progression (mean score: 3.81). While many teachers follow textbook-based methodologies (mean score: 3.56), some adapt their approaches based on contextual needs. Assessment practices are diverse, with positive reception for varied assessment methods (mean score: 3.87) and time-bound assignments (mean score: 3.61). Additionally, teachers employ a broad range of instructional strategies (mean score: 3.81), reinforcing their competency in integrating content and pedagogy. However, refining adherence to textbook methodologies could further enhance instructional effectiveness.

Major Findings of Objective Three

Students' Achievement Test (MCQs) for students' conceptual understanding

The analysis of the students' achievement test (MCQs) reveals varied levels of conceptual understanding in biology across different topics. In Q1, "Why do different species have a different number of chromosomes?", 60.1% of responses were incorrect while only 39.9% were correct, with a mean score of 0.4 (SD = 0.491). This indicates that a majority of students struggled with this concept, suggesting that this area may be either particularly challenging or in need of further instructional reinforcement. In contrast, Q2, "What is the main purpose of photosynthesis in plants?", shows a stronger grasp of the concept, with 70.7% of responses correct (mean = 0.71, SD = 0.456). Similarly, Q3, "How do animals help plants in photosynthesis?", received an even higher correct response rate of 82.3% (mean = 0.82, SD = 0.382), indicating a robust understanding of this interdependent biological process. The comprehension of microbiology concepts is also high, as evidenced by Q4, "Which statement about bacteria is correct?", where 86.9% of responses were correct (mean = 0.87, SD = 0.339). Likewise, Q5, "What is the role of DNA in a cell?", shows that 79.8% of responses were correct (mean = 0.8, SD = 0.403), reflecting strong conceptual understanding in genetics.

Major Findings of Objective Four

Semi Structured Interviews for Headmasters

The findings from the semi-structured interviews with headmasters highlight several key issues related to the implementation of Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) in schools. While most headmasters acknowledged the benefits of CK and PCK in enhancing teaching practices and improving student learning outcomes, challenges remain in their effective integration. Resistance from teachers, infrastructure limitations, and funding constraints emerged as significant obstacles, with some educators hesitant to adopt new pedagogical approaches and technologies. Additionally, content knowledge gaps and time constraints were noted as barriers, as certain teachers lacked expertise in specific subjects. The integration of technology into teaching practices also faced multiple hindrances, including a lack of technical skills among teachers, rigid curriculum structures, and pressure from parents and students to adhere to traditional methods. Some teachers expressed concerns about the risk of failure when implementing new strategies, further complicating the transition to innovative teaching practices.

These findings underscore the need for targeted professional development, better resource allocation, and supportive policies to facilitate the adoption of CK and PCK in schools.

Conclusion

This study underscores the crucial role of Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) in shaping students' conceptual understanding of biology at the secondary school level. The findings reveal that teachers with strong CK effectively convey subject matter, while those with well-developed PCK utilize diverse instructional strategies to enhance student engagement and comprehension. However, the effective implementation of CK and PCK is hindered by several challenges, including teacher resistance, infrastructure limitations, financial constraints, content knowledge gaps, and difficulties in integrating technology due to insufficient training and rigid curricular structures. Additionally, societal pressures from parents and students often reinforce traditional teaching methods, further restricting pedagogical innovation. These challenges highlight the complexities involved in strengthening biology education and the need for a more comprehensive approach to addressing them.

References

Abbitt, J. T. (2011). Measuring technological pedagogical content knowledge in preservice teacher education: a review of current methods and instruments. Journal of Research on Technology in Education, 43(4), 281– 300.

Abell, S. K. (2007). Research on science teacher knowledge. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 1105-1149). Mahwah, NJ: Lawrence Erlbaum Associates.

American Association for the Advancement of Science. (2019). Interdisciplinary learning: Integrating knowledge across disciplines. American Association for the Advancement of Science (AAAS). Retrieved from https://www.aaas.org.

American Institute of Biological Sciences. (2019). Interdisciplinary biology: Advancing science education and research. American Institute of Biological Sciences (AIBS). Retrieved from https://www.aibs.org

American Institute of Biological Sciences. (2019). The Importance of Biology Education.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? Journal of Teacher Education, 59(5), 389-407.

Bureau of Labor Statistics. (2020). Biological scientists. U.S. Department of Labor. Retrieved from https://www.bls.gov

Campbell, N. A., & Reece, J. B. (2008). Biology (8th ed.). San Francisco, CA: Pearson Benjamin Cummings.

Centers for Disease Control and Prevention. (2019). Health education strategies. U.S. Department of Health & Human Services. Retrieved from https://www.cdc.gov/healthcommunication/healthbasics/whatishc.html.

CLARK, V. L. P. & CRESWELL, J. W. 2008. The mixed methods reader, Sage.

Grossman, P. L. (1990). The making of a teacher: Teacher knowledge and teacher education. Teachers College Press.

Cresswell, J. (2013). Qualitative inquiry & research design: Choosing among five approaches.

Grossman, P. L., & Richert, A. E. (1988). Unacknowledged problems in using concept maps in teacher education. American Educational Research Journal, 25(4), 513-536.

HARRIS, J., MISHRA, P. & KOEHLER, M. J. J. O. R. O. T. I. E. 2009. Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. 41**,** 393- 416.

Kagan, D. M. (1992). Implications of research on teacher belief and knowledge for teacher education. Educational Psychologist, 27(1), 65-90.

Koehler, M. J., Cain, W., & Mishra, P. (2013). What is technological pedagogical content knowledge (tpack)?. Journal of Education, 193(3) 13 – 19.

Malik, S., Rohendi, D., & Widiaty, I. (2019, February). Technological Pedagogical Content Knowledge (TPACK) with Information and Communication Technology (ICT) Integration: A Literature Review. In 5th UPI International Conference on Technical and Vocational Education and Training (ICTVET 2018). Atlantis Press.

Masrifah, M., Setiawan, A., Sinaga, P., & Setiawan, W. (2018, September). Profile of senior high school in-service physics teachers' technological pedagogical and content knowledge (TPACK). In Journal of Physics: Conference Series (Vol. 1097, No. 1, p. 012025). IOP Publishing.

MCCAUGHTRY, N. J. T. & TEACHING 2005. Elaborating pedagogical content knowledge: What it means to know students and think about teaching. 11**,** 379-395.

MISHRA, P. & KOEHLER, M. J. (2008) Introducing technological pedagogical content knowledge. annual meeting of the American Educational Research Association, 2008. 16.

MORINE-DERSHIMER, G. & KENT, T. 1999. The complex nature and sources of teachers' pedagogical knowledge. Examining pedagogical content knowledge: The construct and its implications for science education. Springer.

National Academy of Sciences. (2019). Integrating biology and physics: A framework for interdisciplinary science education. National Academies Press. Retrieved from https://www.nap.edu

National Academy of Sciences. (2019). Science and engineering for grades 6-12: Investigation and design at the center. National Academies Press. https://doi.org/10.17226/25216

National Research Council. (2012). A Framework for K-12 Science Education.

National Science Foundation. (2019). Interdisciplinary research: Innovations at the intersection of disciplines. National Science Foundation (NSF). Retrieved from https://www.nsf.gov

SHULMAN, L. S. J. E. R. 1986. Those who understand: Knowledge growth in teaching.15**,**4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1-22.

VEAL, W. R., MAKINSTER, J. G. J. T. E. J. F. R. I. S. & EDUCATION, M. 1999. Pedagogical content knowledge taxonomies.

VOOGT, J., FISSER, P., PAREJA ROBLIN, N., TONDEUR, J. & VAN BRAAK, J. J. J. O. C. A. L. 2013. Technological pedagogical content knowledge–a review of the literature. 29**,** 109-121.

VOOGT, J., FISSER, P., TONDEUR, J. & VAN BRAAK, J. 2016. Using theoretical perspectives in developing an understanding of TPACK. Handbook of technological pedagogical content knowledge (TPACK) for educators. Routledge.

Yamane. T. (1967). rule of thumb for selecting sample size, Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1-23.