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Clinical Reasoning and Decision Making through Knowledge Networks and Abduction: A Sustainable Framework based on Eduinformatics

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Abstract

This study examines the integration of clinical decision making processes with knowledge networks and abductive reasoning in nursing practice, proposing a sustainable framework based on eduinformatics. While clinical reasoning traditionally relies on deductive and inductive approaches, the complexity of modern healthcare demands more sophisticated decision-making methodologies. Through analysis of clinical cases and reasoning patterns, we demonstrate how abductive reasoning complements traditional approaches, particularly in situations where complete information is unavailable. The knowledge network theory provides a structured framework for understanding how clinical knowledge is created, shared, and applied. By integrating these elements through eduinformatics, we develop a comprehensive approach that enhances clinical reasoning capabilities in nursing education and practice. This framework offers a systematic way to improve clinical decision-making while maintaining sustainability in increasingly complex healthcare environments.

Keywords: clinical reasoning, clinical decision making, knowledge networks, abductive reasoning, eduinformatics

1 Introduction

1.1 Background of Clinical Decision Making in Healthcare

The landscape of modern healthcare has undergone significant transformation, characterized by increasing complexity in medical interventions and the growing sophistication of patient care requirements. This evolution has created unprecedented challenges in clinical decision-making, particularly in settings where multiple health conditions and high medical dependency intersect [1]. The integration of various types of knowledge has become essential for providing effective healthcare services in these complex environments.

In recent years, there has been increasing interest in "clinical reasoning" in nursing, with several books featuring "clinical reasoning" in their titles [2] [3]. This heightened attention is believed to be related to the inclusion of "clinical reasoning" as one of the common subjects in the training system for nurses related to specific medical procedures (hereinafter referred to as the training system) that began in 2015 [4].

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The demands on healthcare professionals, particularly nurses, have escalated with the introduction of new technologies and treatment modalities. This transformation has necessitated a more structured approach to knowledge creation and utilization, leading to the development of new frameworks for understanding and implementing clinical decision-making processes [5]. The intersection of traditional nursing practice with advanced medical technologies has created a unique challenge in developing appropriate decision-making methodologies.

1.2 Knowledge Networks and Eduinformatics

The concept of knowledge networks has emerged as a fundamental framework for understanding how healthcare professionals develop and utilize clinical knowledge. These networks represent complex systems of interconnected knowledge that evolve through distinct stages of growth, including propagation, mixing, and creation [6]. The dynamic nature of these networks reflects the complex nature of modern healthcare delivery systems.

Eduinformatics, a novel interdisciplinary field combining education and informatics, provides a theoretical foundation for understanding these knowledge creation processes [6] (Fig. 1). This field has become particularly relevant in the context of data-driven decision-making approaches in healthcare education and practice. The integration of educational theory with informatics principles offers new perspectives on how knowledge is created, shared, and applied in clinical settings.

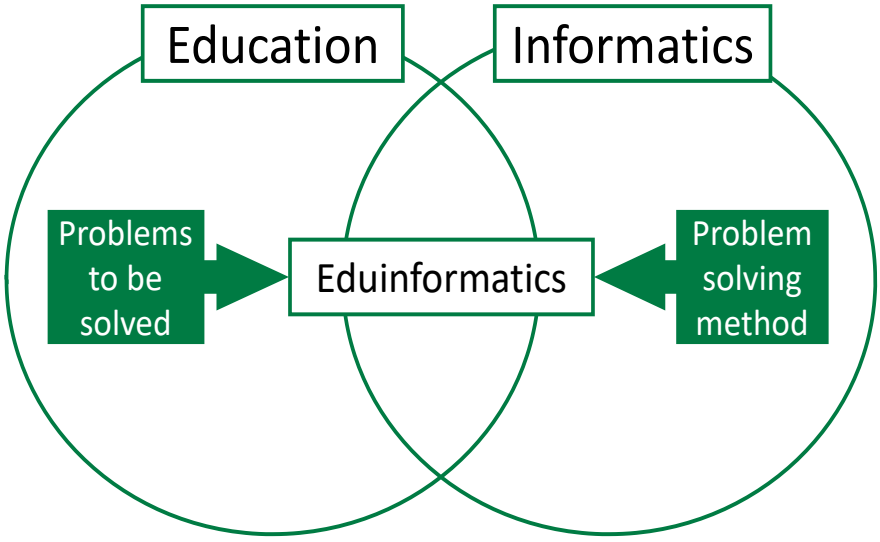

Figure 1: Concept of Eduinformatics [5]

The application of knowledge networks within the eduinformatics framework has created new opportunities for understanding and improving clinical decision-making processes. This approach recognizes the interconnected nature of knowledge creation and application, particularly in complex healthcare environments where multiple factors must be considered simultaneously.

1.3 Current Status of Clinical Reasoning

In medicine, clinical reasoning is clearly defined as "the thought process and content used to identify and resolve patient illnesses" [7]. On the other hand, in nursing, it has been pointed out that the definition content is broadly divided into two categories: the content included in the nursing process that nurses have traditionally performed and the thought process and methods related to diagnosis performed by doctors [4].

Generally speaking, when it comes to reasoning, most people might think of induction and deduction. However, Peirce, an American logician and scientific philosopher, showed in the 18th century that there exists another notable method or mode of thinking called abduction or retroduction in addition to induction and deduction, and summarized these three thinking methods [8].

The evolution of clinical reasoning in nursing practice has been influenced by various factors, including technological advancement, changing patient demographics, and increasing complexity of care requirements. The traditional approaches to clinical reasoning are being challenged by these changes, necessitating a more comprehensive understanding of how nurses develop and apply clinical knowledge [9].

1.4 The Role of Abductive Reasoning

We have been conducting research on the minimum essentials of mathematical and data science education in basic nursing education (JSPS KAKENHI Grant Number 20K10653) in response to the "AI Strategy 2019," which states that "approximately 500,000 students per year from all universities and technical colleges, regardless of their arts or science background, will learn basic level mathematical, data science, and AI in their courses" [10].

The emergence of the Abduction, Abstract Degree and Urgency Matrix (ABDU-M) represents a significant advancement in the application of abductive reasoning to Institutional Research (IR) (Fig. 2). This framework provides a structured approach to hypothesis generation and testing, particularly valuable in complex clinical scenarios where traditional reasoning methods may be insufficient [11].

The integration of abductive reasoning with existing clinical decision-making frameworks has created new opportunities for advancing nursing practice. This approach recognizes the importance of hypothesis generation in clinical reasoning, particularly in situations where complete information may not be immediately available [12].

1.5 Research Objectives

This study aims to examine the integration of knowledge networks and abductive reasoning in clinical decision-making, with a specific focus on developing a sustainable framework based on eduinformatics. The research addresses three key questions:

How can knowledge networks enhance clinical decision-making processes in nursing practice?

What role does abductive reasoning play in deepening clinical reasoning capabilities?

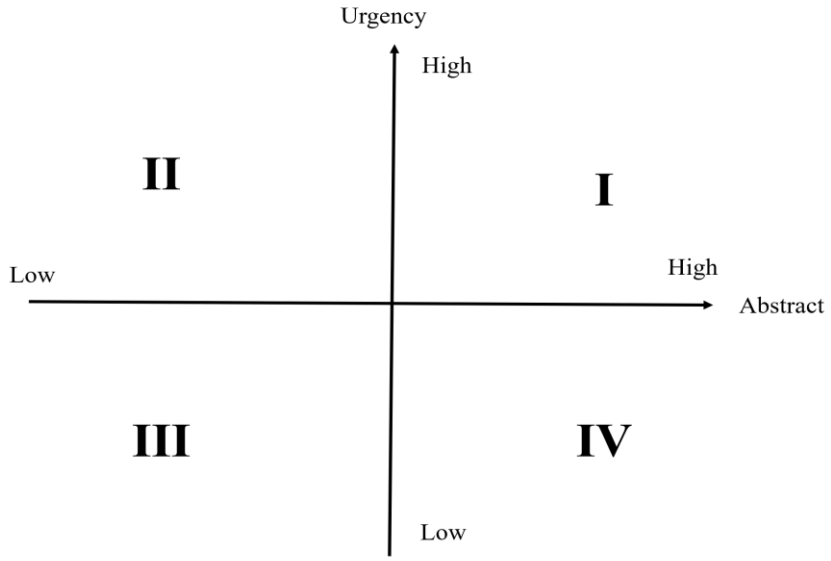

Figure 2: Abduction, Abstract Degree and Urgency Matrix (ABDU-M) [11]

How can eduinformatics support the integration of these approaches in nursing education and practice? [9]

Despite abduction, induction, and deduction being various forms of reasoning in science, induction and deduction are the most commonly used in nursing literature [12]. While some scholars have pointed out that abduction is considered a precondition for scientific research as it generates hypotheses and theories prior to deductive and inductive reasoning, it has been largely ignored in nursing research, reflecting nursing researchers' relative indifference to this concept [13].

The significance of this research lies in its potential to bridge the gap between theoretical understanding and practical application of clinical reasoning in nursing. By integrating knowledge networks, abductive reasoning, and eduinformatics, this study aims to develop a more comprehensive and effective approach to clinical decision-making in nursing practice [1].

2 Methods

This study employs a theoretical analysis approach integrating three key methodological components: the analysis of traditional reasoning methods (deduction and induction), the examination of abductive reasoning, and the application of knowledge network theory. The methodology is structured to address the research objectives while maintaining practical applicability in clinical settings [14].

2.1 Deduction and Induction

Since induction and deduction can be said to be "continuous" [15], we will reorganize both in terms of clinical nursing to confirm this point.

Induction is a method of reasoning that derives general laws or principles from specific observations or experiences. For example:

[Induction]

Patient A with effort angina experienced chest pain during exertion

Patient B with effort angina experienced chest pain during exertion

Patient C with effort angina experienced chest pain during exertion

→ [Conclusion] People with effort angina experience chest pain during exertion

In this way, when multiple patients have the same disease and show the same symptoms, a general conclusion is drawn that the chief complaint of that disease is XX. This reasoning method is called expansive reasoning, as shown in Figure 2, because it is a process of extracting general laws from individual cases and is frequently used in clinical settings.

On the other hand, deduction is a method of reasoning that draws conclusions that apply to specific cases from already known general principles or laws. For example:

[Deduction]

People with effort angina experience chest pain during exertion.....①

→ Patient D has effort angina.....②

→ [Conclusion] Patient D will experience chest pain during exertion.....③

This is a method of reasoning that differs from induction and is called analytical reasoning (Figure 3).

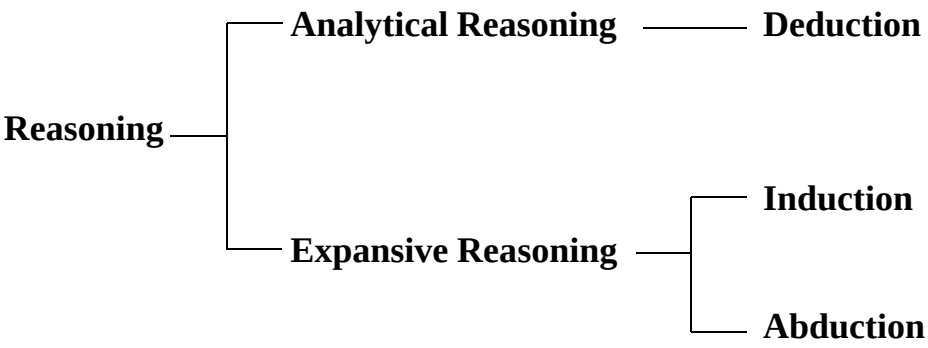

Figure 3: Classification of Reasoning Types (from [8])

The integration of these reasoning methods in clinical practice requires careful consideration of their respective strengths and limitations. While induction helps in pattern recognition and hypothesis generation, deduction provides a structured approach to applying established knowledge [16].

2.2 Analysis Framework for Abductive Reasoning

To systematically analyze the role of abductive reasoning in clinical practice, we developed an analytical framework based on the following components [22]:

1. Pattern recognition in clinical scenarios
2. Hypothesis generation processes
3. Integration with existing knowledge networks
4. Application of the ABDU-Matrix

The biggest difference between the two is that in deduction, since there is a major premise, a minor premise, and a conclusion is derived, it is called a syllogism, and if the premises are correct, the conclusion is always correct (truth preservation), but in induction, since the conclusion is drawn from individual cases or events (in the above example, patient A, patient B, patient C), the conclusion cannot be said to be logically always correct.

The ABDU-Matrix provides a structured approach to evaluating clinical scenarios based on both their urgency and level of abstraction. This framework helps practitioners navigate complex clinical situations where traditional reasoning methods may be insufficient [17].

3 Results and Discussions

3.1 Necessity and Importance of Abductive Reasoning

The integration of knowledge networks in clinical reasoning provides a structured framework for understanding how healthcare professionals develop and utilize knowledge [18]. This framework becomes particularly relevant when examining how nurses navigate complex clinical scenarios where traditional reasoning methods may be insufficient [19].

Despite induction, deduction, and abduction being various forms of reasoning in science, the literature on clinical reasoning shows different ways of thinking, as shown in Table 1. These thinking styles reveal that while various forms of reasoning are discussed, abduction is notably absent from the traditional literature on clinical reasoning in nursing [13].

Table 1. Thinking Methods Presented in Literature on Clinical Reasoning

Clinical Reasoning Required for Clinical Judgment for Nursing Students[2]	Introduction to Clinical Reasoning for Confident Assessment [3]	What is Clinical Reasoning [20]
・Thorough verification method ・Deductive method ・Inductive method ・Pattern recognition ・Heuristic (experiential) ・Intuitive thinking ・Analytical thinking	・Pattern recognition ・Multi-branching method ・Hypothetico-deductive method ・Thorough examination method ・Systematic assessment ・Narrative reasoning method	・Pattern recognition ・Hypothetico-deductive method ・Diagnostic criteria/algorithm ・Thorough examination method ・etc.

Let us describe one of the authors' clinical nursing experiences. One day, a new nurse working in the same department received a nurse call from Patient E, who was hospitalized for angina, saying that chest pain was occurring, so she headed to the patient's bedside. The attending physician's instructions for the patient's chest pain attack were sublingual administration of nitroglycerin. When the new nurse did not return to the staff station for a while, the leader nurse who was concerned visited the room and found that although she had administered nitroglycerin sublingually as instructed, she was standing still because the chest pain did not subside. During this time, the new nurse tried spraying several times, thinking that the nitroglycerin spray might not be ejecting properly.

When analyzing the new nurse's thought process at this time, it can be surmised that she probably reached a stalemate because there was a contradiction between the thought-based conclusion derived from the major premise "sublingual administration of nitroglycerin is effective for angina chest pain attacks" and the minor premise "chest pain attacks disappear when nitroglycerin is administered sublingually," leading to "Patient E's chest pain will disappear," and the fact that "chest pain attacks do not subside even when nitroglycerin is administered sublingually."

This case exemplifies how knowledge creation occurs through the three stages identified in the knowledge network growth model: propagation, mixing, and creation [18]. The ABDU-Matrix framework suggests that such clinical scenarios require movement between different levels of abstraction in reasoning [11].

3.2 Application of Abductive Reasoning in Clinical Practice

While there may be countless such examples in nursing practice, what is needed at this time is abduction as a way of thinking/mode. Below, we will demonstrate the reasons for this.

First, to clarify the differences from induction and deduction, let us explain the mode of abduction using the example of effort angina used in the [Deduction] explanation section above.

First, based on the same major premise as above, if we write:

[Abduction]

People with effort angina experience chest pain during exertion.....④ (same as ① above)

→ Patient F is experiencing chest pain.....⑤

→ [Conclusion] Patient F probably has effort angina.....⑥

This example demonstrates the integration of knowledge network theory and clinical reasoning. The tag-based model [7] suggests that clinical knowledge is organized through multiple interconnected layers, allowing practitioners to move flexibly between different types of reasoning.

3.3 Integration of Multiple Reasoning Methods in Clinical Practice

Looking at the example of deduction and the rewritten example of abduction, in the case of deduction, if both "People with effort angina experience chest pain during exertion (① above)" and "Patient D has effort angina (② above)" are correct, then the conclusion "Patient D will experience chest pain during exertion (③ above)" is necessarily correct. However, in the case of abduction, even if both "People with effort angina experience chest pain during exertion (④ above)" and "Patient F is experiencing chest pain (⑤ above)" are correct, since there are several possible causes of chest pain such as myocardial infarction or aortic dissection, the conclusion "Patient F probably has effort angina (⑥ above)" is not necessarily correct.

Abduction can also be written as follows:

[Abduction]

Patient F is experiencing chest pain (same as ⑤ above)

→ People with effort angina experience chest pain during exertion (same as ④ above)

→ [Conclusion] Patient F probably has effort angina

This flexible approach to clinical reasoning aligns with the principles of eduinformatics [5], where knowledge creation and utilization are viewed as dynamic processes that require continuous adaptation and refinement. The ABDU-Matrix provides a structured framework for managing these complex reasoning processes [11].

3.4 Practical Implications and Future Directions

Based on these points, when analyzing the case of the new nurse mentioned above, we can see that in clinical reasoning, relying solely on deduction can lead to preconceptions. That is, deduction has truth preservation in its conclusions, which can lead to fixation on the conclusion. In this case, it is thought that being caught up in the idea that nitroglycerin sublingual administration should work for angina led to the situation of spraying nitroglycerin spray multiple times.

However, at this point, if this new nurse had been able to switch to the thought that there is not just one cause of chest pain using abduction, she might have been able to transition to different appropriate nursing practice rather than the act of spraying nitroglycerin spray multiple times. Specifically, based on the premise (existing knowledge) that "if there is no effect from nitroglycerin, there is a possibility of progression to myocardial infarction," it is believed that she could have immediately made the judgment to take a 12-lead ECG.

The knowledge network approach suggests that such clinical decision-making processes can be enhanced through the systematic organization of clinical knowledge. In particular, the tag-based knowledge network model provides a framework for understanding how different pieces of clinical knowledge can be effectively integrated and utilized in practice.

In fact, when the leader nurse immediately took a 12-lead ECG, ST elevation was clearly observed on the ECG, so she immediately reported to the attending physician, and emergency percutaneous coronary intervention (PCI) was performed, avoiding any issues, and Patient F was able to be discharged safely afterward.

This case demonstrates how the integration of knowledge networks, abductive reasoning, and the ABDU-Matrix can support more effective clinical decision-making. The eduinformatics framework provides a theoretical foundation for understanding these complex processes and suggests approaches for improving clinical education and practice.

4 Conclusion

This study set out to address three key research questions:

(1) How can knowledge networks enhance clinical decision-making processes in nursing practice?

(2) What role does abductive reasoning play in deepening clinical reasoning capabilities?

(3) How can eduinformatics support the integration of these approaches in nursing education and practice?

Through our theoretical analysis and clinical case studies, we have demonstrated that knowledge networks provide a structured framework for organizing and accessing clinical knowledge, enabling nurses to navigate complex decision-making scenarios more effectively. The three-stage growth model of knowledge networks - propagation, mixing, and creation - offers a systematic approach to understanding how clinical knowledge evolves and is applied in practice. Regarding the role of abductive reasoning, our analysis reveals its crucial importance in situations where traditional deductive and inductive reasoning alone are insufficient. The clinical case presented in this study clearly illustrates how abductive reasoning enables nurses to generate and

test hypotheses in situations with incomplete information, potentially leading to better patient outcomes. This was particularly evident in the case where recognizing the limitations of deductive reasoning and employing abductive thinking could have led to earlier identification of myocardial infarction. The integration of these approaches through eduinformatics has proven to be particularly effective, as demonstrated by the ABDU-Matrix framework, which provides a structured approach to managing complex clinical scenarios. This integration offers a sustainable and practical framework for improving clinical decision-making in nursing practice, while also providing a theoretical foundation for nursing education. The framework's effectiveness is evident in its ability to bridge the gap between theoretical understanding and practical application, particularly in complex healthcare environments where multiple factors must be considered simultaneously.

Acknowledgement

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References

[1] Y. Nakata, K. Bannaka, T. Kunisaki, T. Kirimura, and K. Takamatsu, "Data-driven approach essential for mathematical and data science education in basic nursing education: to avoid a belief conflict between methodologies," *Bulletin of Kobe Tokiwa University*, vol. 15, pp. 12–19, 2022, doi: 10.20608/00001150.

[2] M. Yukihiro, *Clinical Reasoning Required for Clinical Judgment for Nursing Students*. vexon international, 2023.

[3] O. Tomoko, *Introduction to Clinical Reasoning for Confident Assessment (Japanese)*. Medicus Shuppan, 2019.

[4] H. Kaya and H. Chifuyu, "Overview of the Definition of 'Clinical Reasoning' in Nursing (Japanese)," *Bulletin of Kobe City College of Nursing*, vol. 25, pp. 1–7, 2021.

[5] K. Takamatsu, K. Murakami, T. Kirimura, K. Bannaka, I. Noda, L. R.-J. Wei, K. Mitsunari, M. Seki, E. Matsumoto, M. Bohgaki, A. Imanishi, M. Omori, R. Adachi, M. Yamasaki, H. Sakamoto, K. Takao, J. Asahi, T. Nakamura, *et al.*, "'Eduinformatics': A new education field promotion," *Bulletin of kobe Tokiwa University*, vol. 11, pp. 27–44, 2018, doi: 10.20608/00000958.

[6] K. Takamatsu, Y. Kozaki, K. Murakami, A. Sugiura, K. Bannaka, K. Mitsunari, M. Omori, and Y. Nakata, "Review of Recent Eduinformatics Research," in *2019 IIAI International Congress on Applied Information Technology (IIAI-AIT)*, 2019, p. submitted.

[7] K. Takamatsu, I. Noda, B. Kenya, T. Nakagawa, Y. Kozaki, K. Mitsunari, M. Omori, R. Adachi, and Y. Nakata, "A New Concept of ICT on Eduinformatics in Higher Education," in *Proceedings of Sixth International Congress on Information and Communication*

Technology: ICICT 2021, London, Volume 1 (Lecture Notes in Networks and Systems Book 235), Springer Nature, 2022, pp. 693–700. doi: 10.1007/978-981-16-2377-6_64.

[8] Y. Yuji, *Abduction: Logic of Hypothesis and Discovery (Japanese)*. Keiso Shobo, 2007.

[9] K. Takamatsu, I. Noda, K. Bannaka, K. Murakami, Y. Kozaki, A. Kishida, H. Kabutoya, K. Mitsunari, R. Adachi, M. Omori, and Y. Nakata, "A new Concept of Digital transformation (DX), and Institutional Research (IR), and Information and Communication Technology (ICT) based on Eduinformatics in Higher Education," in *7th International Congress on Information and Communication Technology*, 2022, p. submitted.

[10] Integrated Innovation Strategy Promotion Council Decision, "AI Strategy 2019," 2019. https://www8.cao.go.jp/cstp/ai/aistratagy2019en.pdf (accessed Nov. 01, 2024).

[11] K. Takamatsu, I. Noda, K. Bannaka, K. Murakami, T. Kirimura, T. Kunisaki, R. Kozaki, S. Matsumoto, A. Kishida, H. Ito, A. Ito, S. Imai, K. Mitsunari, M. Omori, M. Mori, and Y. Nakata, "Abduction, Abstract Degree and Urgency Matrix (ABDU-M) for Flexible/Agile Higher Education Reform based on Eduinformatics," in *Intelligent Sustainable Systems Selected Papers of WorldS4 2023*, 2024, p. in press.

[12] B. Karlsen, T. M. Hillestad, and E. Dysvik, "Abductive reasoning in nursing: Challenges and possibilities," *Nurs. Inq.*, vol. 28, no. 1, p. e12374, Jan. 2021, doi: 10.1111/nin.12374.

[13] M. Lipscomb, "Abductive reasoning and qualitative research: Abductive Reasoning," *Nurs. Philos.*, vol. 13, no. 4, pp. 244–256, Oct. 2012, doi: 10.1111/j.1466-769x.2011.00532.x.

[14] N. A. Mirza, N. Akhtar-Danesh, C. Noesgaard, L. Martin, and E. Staples, "A concept analysis of abductive reasoning," *J. Adv. Nurs.*, vol. 70, no. 9, pp. 1980–1994, Sep. 2014, doi: 10.1111/jan.12379.

[15] Y. Nakata, K. Bannaka, T. Kunisaki, T. Kirimura, and K. Takamatsu, "Abduction essential for mathematical and data science education in basic nursing education: to avoid a belief conflict between methodologies," *Bulletin of Kobe Tokiwa University*, vol. 16, pp. 52–59, 2023.

[16] K. Eriksson and U. A. Lindström, "Abduction--a way to deeper understanding of the world of caring," *Scand. J. Caring Sci.*, vol. 11, no. 4, pp. 195–198, 1997, doi: 10.1111/j.1471-6712.1997.tb00455.x.

[17] M.-B. Råholm, "Abductive reasoning and the formation of scientific knowledge within nursing research: Abductive Reasoning Within Nursing Research," *Nurs. Philos.*, vol. 11, no. 4, pp. 260–270, Oct. 2010, doi: 10.1111/j.1466-769X.2010.00457.x.

[18] T. Kirimura, K. Takamatsu, K. Bannaka, I. Noda, M. Omori, R. Adachi, K. Mitsunari, and Y. Nakata, "Three-step knowledge network model," *Bulletin of Kobe Tokiwa University*, vol. 9, pp. 78–86, 2016, [Online]. Available: https://cir.nii.ac.jp/crid/1050845762577181568

[19] K. Takamatsu, K. Bannaka, T. Kirimura, I. Noda, K. Murakami, K. Mitsunari, and Y. Nakata, "Tag-based knowledge network models," *Bulletin of Kobe Tokiwa University*, vol. 10, pp. 51–60, 2017.

[20] N. Senka, "What is Clinical Reasoning (Japanese)," 2018. https://knowledge.nurse-senka.jp/226658/ (accessed 20241101).