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Computational Thinking: The Essential Skill for being Successful in Knowledge Science Research

Adam Mukharil Bachtiar

School of Knowledge Science, Japan Advanced Institute of Science and Technology, 1-8 Asahidai, Nomi Shi, Ishikawa, Japan

*Corresponding Email: s2220401@jaist.ac.jp

ABSTRACTS

The VUCA world concept was established in 2016 as the new challenge universe in the 21st century. Humans live in Society 5.0 and the VUCA world simultaneously. The digital word has been a noisy word since then. There are a lot of requisite skills to be a survival kit for this kind of era. The VUCA world's affection is spreading in the way of thinking and creating innovation, especially in the research domain. As a newcomer, Knowledge Science should state the requisite skills for its researchers to conduct their research successfully. Many researchers offered computational thinking as a candidate for an essential skill to satisfy the effect of the VUCA world. This study was focused on conducting a descriptive analysis method based on several literature reviews for mapping how computational thinking can serve as a best practice for Knowledge Science research. This study successfully revealed the connection between Computational Thinking.

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1. INTRODUCTION

We are living in Society 5.0 with a focus on increasing the capability of human-being to create innovation (Carayannis & Morawska-Jancelewicz, 2022). The limitation between the real and digital world seems to fade out. The interaction among humans is very intense in social media. Digitalization is a word that the constituent parties in society should fulfill. Higher education plays a significant role in ensuring the availability of human resources with requisite skills (Shin. J.C., 2015).

Digitalization leads society to a new concept called the VUCA world (Mack &

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Khare, 2016). The extra challenge was added to society as the effect of this concept. The VUCA world offered the uncertainty and unpredictable future that break in the stability of the digital era (Johansen & Euchner, 2013). The VUCA presence threatens the process of creating innovation in the digital platform. Society 5.0 has stated the requisite skills for humans in the 21st century as the primary skills to be achieved by undergraduate or graduate students. Communication, critical thinking, collaboration, creativity, and problem-solving skills are some powerful words that appear in the list of requisite skills for the 21st century (Gutiérrez-Núñez et al., 2022; Semsri et al., 2022; Van Laar et al., 2020). But the uncertainty word needs to be satisfied and force society to add extra skill as the complement.

In the middle of the chaos, Knowledge Science became more mature nowadays as one of the knowledge do- mains. The hard and soft research type was published to encourage the role of Knowledge Science in the higher education domain (Huang et al, 2016). Without giving enough space for debating about the position of Knowledge Science com- pared with the existing knowledge domain, many researchers in the field have successfully filled the gap in the research in Information Science. The granularity between information and knowledge creates a summary that Knowledge Science is well deserved as the new domain (Zins, C. 2006). Like the other field, Knowledge Science needs to answer the challenge given by the VUCA world. Future researchers in this field should own the extra skills, excluding the essential skills in the 21st century, to survive and continue to produce the following research.

Some recent research shows the appearance of a new skill called Computational Thinking. Most studies reveal the importance of Computational Thinking in education, including the Knowledge Science domain. That thinking method successfully demonstrated the change in human behaviors in solving the problem (Sermsri et al, 2022; Kong, S. C. 2022; Yasar et al, 2023). The way of teaching is also got affected by Computational Thinking. Today's scientists not only leverage computational tools to conduct their investigations but often must also contribute to designing the computational tools for their specific research (Hurt et al., 2023). Because of this need, this study is focused on revealing the intuition and the way of thinking of Computational Thinking in conducting Knowledge Science research. Using descriptive analysis, this study intui- tively examined each element of Computational Thinking in some Knowledge Science research to be a general overview for future researchers in the Knowledge Science field.

2. METHOD

This study involves two significant concepts: Computational Thinking and Knowledge Science. Both seem dif- ferent, but Computational Thinking is a general thinking skill that can exist in every domain. The first sub-section will focus on explaining Computational Thinking, followed by the second, which focuses on explaining Knowledge Science as the domain.

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2.1. Computational Thinking

Jeannette Wings, the founder of Computational Thinking (also known as CT), used words such as problem-solving method and how computers execute the solution to give a powerful understanding of Computational Thinking (Wing. J. M., 2014).

There is one famous statement from her that if one person thinks using Computational Thinking, then the person will involve in formulating problems and their solutions so that the solutions are represented in a form that an information-processing agent can effectively carry out (Shute & Asbell-Clarke, 2017).

The word "an information-processing agent" refers to the computer. Some research demonstrates how Computational Thinking is the essential thinking method across many fields. Tables 1 and 2 show the research on Computational Thinking in some science fields, either natural or social science.

Table 1. Computational Thinking in Some Science Research

Study	Explanation
Qin, H., 2019	This study comprehensively develops how CT helps the participants learn about Bioinformatics using com- puter laboratory exercises. The researchers can examine how to implement CT early in Bioinformatics learning even though they cannot determine which elements are significant
Weintrop et al., 2016	This study argued about the position of CT in supporting the Mathematics and Science context. The modeling and simulation became the most significant part affected by CT
Chongo et al., 202	Chemistry also became one field that CT invaded. The experiment using plugged and unplugged CT method is the central part of this study
Güven & Gulbahar, 2020	Social science will be the last field to be predicted as CT invades. This study provided an excellent com- prehensive about how to implement CT in social studies

Table 2. Four elements of Computational Thinking (Mack & Khare, 2016)

Element of CT	Explanation
Abstraction	a. Determine the fundamental problem from all the phenomena. b. Reformulate into solvable and can be familiarized as the computational case
Decomposition	Break down the problem into several sub-problems that can be more solvable intuitively
Algorithm	Construct a series of the structured process to be followed in solving the problem
Pattern Recognition	Finding the similarity and shared characteristics between the problem

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Those studies well-explained that CT can be a mature thinking skill in a short time after being declared by the founder. To think using this approach, the researchers should implement four elements of CT. With those ele- ments, CT is possible to be implemented.

2.2. Knowledge Science

Based on Nakamori (2011), Knowledge Science is an emerging discipline resulting from the demands of a knowledge-based economy and information revolution.

The diversity between information and knowledge triggered the shift of the field's name from Information Science to Knowledge Science. Changing the area's name reflects that current information science primarily focuses on exploring the mediating aspects of human knowledge (Zins, C, 2006).

Unlike Information Science, which focuses on manipulating the form and structure of information, Knowledge Science concentrates on optimizing the knowledge creation process either by producing new knowledge using some methodologies or serving the optimization of human and social concepts in the knowledge creation process.

There are two classifications of research in Knowledge Science (Huang et al., 2016; Hlupic et al, 2002). The classification is based on the type of process in the Knowledge Management area, which is a significant area in the Knowledge Science field. Figure 1 shows the research classifications in the Knowledge Science area. Both types share the central role of Knowledge Science, such as knowledge creation, knowledge sharing, knowledge management, and knowledge evaluation equall.

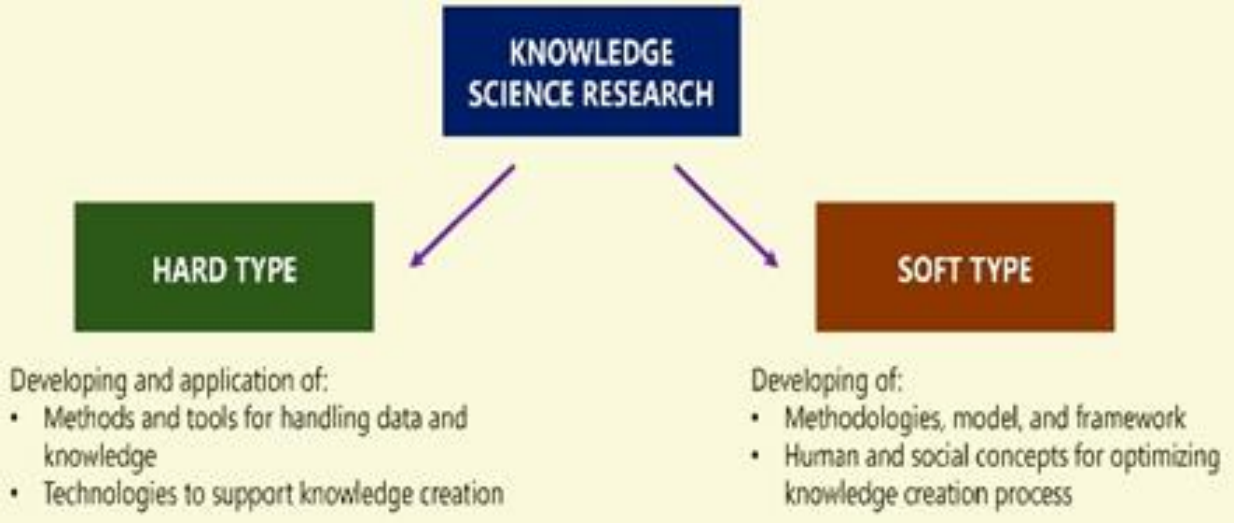

Fig. 1. Two classifications in knowledge science research

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3. RESULTS AND DISCUSSION

3.1. Examples of hard and soft-type research

Some examples of each type of Knowledge Science research were represented in this study before mapping each element of CT into the research. Based on the examples, the intuition for making differences between hard and soft-type research in Knowledge Science can be understood. Table 3 shows some examples of hard-type Knowledge Science research in the School of Knowledge Science, JAIST. Table 4 shows the opposite of the hard-type research, which is soft-type research in the Knowledge Science domain.

Table 3. Examples of hard-type Knowledge Science research

Research	Short Summary
Ono et al, 2022	This research produces technology for Skiers learning using Virtual Reality. Deep learning was used to recognize the skiing posture to be evaluated
Tan et al, 2019	This research produces knowledge in the form of infographics about catalyst degradation mechanisms based on operand Spectro imaging and unsupervised learning from 3D Images.
Hamanaka et al, 2016	This research focused on implementing Lerdahl and Jackendoff's (1983) Generative Theory of Tonal Music (GTTM) to generate new music based on the training data
Miyata et al., 2012	This research generates several procedural technologies that can be used to generate pattern images (3D models).
Torii et al., 2022	This research predicts movement characterizes the degree of animacy and measures it using Granger causality.

Table 4. Examples of soft-type Knowledge Science research

Research	Short Summary
Sinthupundaja et al, 2019	This research examined the importance of the causal combinations of knowledge-acquisition conditions using fuzzy set qualitative comparative analysis.
Shahzad et al, 2016	This research aimed to identify if integration between knowledge strategy and knowledge management (KM) processes leads to organizational creativity and performance.
Hashimoto, 2006	This research focused on modeling to clarify the evolutionary process of language, and evolutionary eco- nomics defines the dynamics of economic phenomena.
Uchihira et al, 2012	This research generated a model to optimize the knowledge transfer process in R&D Project Management.
Kim, 2017	This research is aimed to identify the factors that influence the creation of innovative ideas. The two work- shops were conducted to reveal influential factors.

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3.2. Abstraction for simplification

The intuition behind abstraction is to determine the essential part of the problem and generalize the problem to find its proper form. It can simplify the complex problem to become an intuitive and identified problem. Some unnecessary elements of the problem can be excluded so that the focus of researchers increases simultaneously. For example, there are studies by Hamanaka et al., 2016 and Ohmura et al. about generating music based on the relationship using lattice probability distribution (Ohmura et al, 2018). That study found the essence of the relationship between the tonal in one music. Then, the relationship was used to generate new music. Figure 2 is the overview of the abstraction in the research. In the soft-type, abstraction can be used for generalizing the procedure and its problem into one model. Then, this model will be improved during the research. The famous abstraction result in soft-type research is the SECI model that focuses on optimizing the knowledge creation process in one organization (Farnese et al, 2019).

3.3. Decomposition for reducing the complexity

The intuition behind the decomposition is breaking down the identified problem into several easy-to-chunk prob- lems. The primary strategy is about divide and conquers, which will lead the researchers to the estimated solution. In some research, decomposition is not easy, especially when the problem involves one complex system. Soft system methodology and i-System can decompose the complexity among the constituent party followed by their emergence (Nakamori, Y, 2011; Mingers et al, 1992). The decomposition in Knowledge Science research can be used to examine the interventions in one i-System for later, the solution will be recognized by the three dimensions, such as scientific, collaboration, and creative dimension. In the end, the three solutions offered by each dimension will be integrated in the final phase of the i-System.

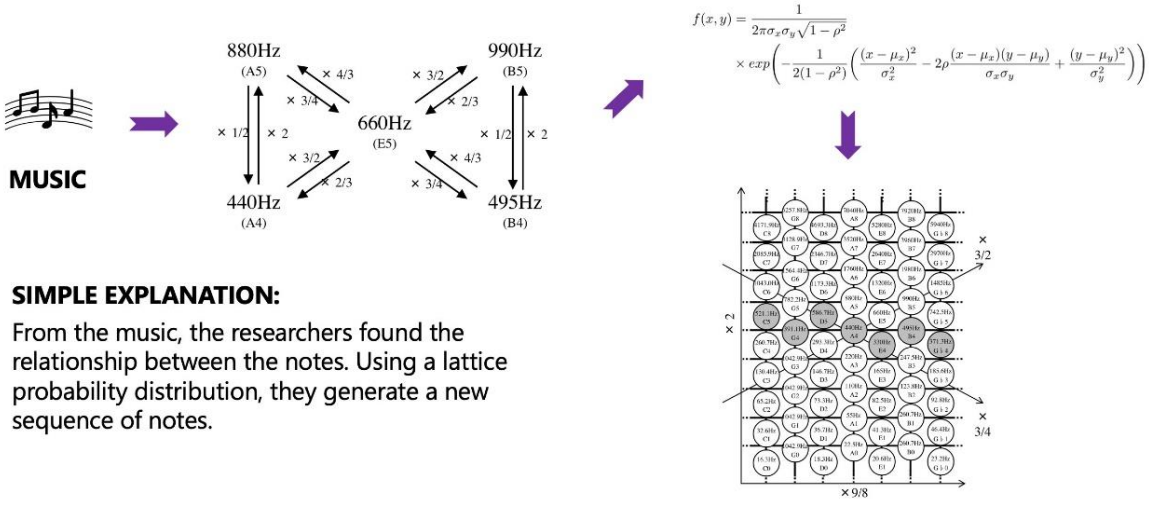

Fig. 2. The abstraction of tonal music generation

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The study by Kim, E., 2017 has successfully demonstrated how the decomposition worked well. The study is focused on revealing the influential factors in idea generation and enhancing them using analogical thinking.

The experiment in that study was divided into two workshops. The first workshop focused on revealing the influ- ential factors, and, in the end, three influential factors were revealed. Then, the second workshop focused on enhancing those factors using analogical thinking.

The conclusion in one research can be achieved through several processes. Each process produces the output represented as the input in the following procedure. The properness to break down the problem, especially to be some processes that can be parallelized, will increase the efficiency and optimal level to achieve successful research.

3.4. Algorithm to Lead the Research

The algorithm is a very familiar element among all the CT's elements. It is mandatory for the researchers to build a structured and sequenced process to lead the problem into the solution. In Knowledge Science research, the algorithm can play a role as the methodology in one research.

The study from Miyata, K., 2012 demonstrated the algorithm in the form of procedural technology for pattern generation or 3D pattern generation. The pattern can be used in a Kimono or Building Structure. Step-by-step how the procedural technology was constructed from the actual pattern is one clear example of how the algorithm took an essential part in this research.

Another example algorithm can play a role as a procedure about how to conduct the experiment workshop. Uchihira et al., 2012 experimented with making a model for optimizing the knowledge transfer process in research and development projects. The algorithm helped the study to illustrate the flow in a structured project case and to conduct an internalization workshop that consisted of six steps. Each step is well-structured. The algorithm is about not only structuring the programming process but also the experimental process.

3.5. Pattern Recognition for finding the similarity

This element plays a significant role in satisfying the uncertainty. Rather than finding similarities, some research- ers often focus on finding the differences among the research. Most of the study is excellent in generating new approaches or results. Even though they seem to be different, they have connected to each other.

The five examples of hard-type Knowledge Science research in Table 3 focus on finding the hidden knowledge using several methods in Knowledge Discovery Methodology. The differences are in the source and form of the knowledge. Similar connecting lines also happen in soft-type Knowledge Science research. The experimental method and the pro- posed model are the shared characteristic between studies. The differences in the domain and the design of exper- iments. Using the capability for finding the similarity can help the researchers to shorten the time for getting the intuition behind the research. From the similarity, they can mark the area in the research domain map that has already been invaded by the other researchers and find the gap between them. Table 5 shows similarities in some research in Tables 3 and 4.

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Table 5. Similarities between the research on the School of Knowledge Science in JAIST with other research outside JAIST

Research	Result of Research	Similar Research as an Evidence
Ono et al, 2022	The proper interaction model for VR to help novice Skiers	Similar research was found in creating an interaction model for Elder Skiers using VR technology. The recent study involved deep learning in evaluating the properness of body posture when skiing.
Tan et al, 2019	The similarity concepts and infographics that were produced by the unsupervised learning in the experimental material	Several concepts of data analytics and machine learning can be applied in material science. Unsupervised learning was found inone study to be a knowledge discovery process in grouping Microstructure material. The experimental object and the intention of data analytics can be a differentiating factor between the studies.
Hamanaka et al, 2016	The relationship rules between the tune in music for generating new music. The vertical rule is an outstanding result of this research.	There is similar research about the vertical pattern in music and how to discover it. The discovery process is called Computational Music Analysis. Even though the similarity was so high, the difference is in the form of explicit knowledge produced by the algorithm.
Torii et al, 2022	The pattern of movement characteristics was measured by the degree of animacy and Granger Causality for the robotic domain	The collision prediction from the robotic movement scenario also resulted from another research. The subdomain from the studies is different, and the focus of movement prediction can differ from the studies.
Sinthupundaja et al, 2019	The concept of the causal combinations of knowledge-acquisition condition	Rather than using fuzzy logic, the other study used Bayesian Network as their primary method to reveal the causal combination of the knowledge-acquisition condition. The dissimilarity also can be found in the proposed concept of knowledge acquisition.
Shahzad et al, 2016	The validated research model of the hypothesis about the integration between knowledge strategy and nowledge management and its correlation to organizational creativity and performance	There are some studies about integrating other possible factors into knowledge management strategy. This further study focused on integrating the aspect of intellectual capital into knowledge management. The dissimilarity factors are the proposed integrated factors, and the destination of the effect comes from the integration procedure.
Hashimoto, 2006	The new pattern when doing recursion is to make the hierarchical structure	One research mentioned several patterns in the linguistic domain. Both studies are about finding a pattern in the linguistic model, but the methods used are different and also for their intention.

4. CONCLUSION

From the revealing process of CT in some Knowledge Science research, there are some conclusions for this research, such as: (a) Computational thinking is a complementary skill to 21st-century skills. (b) The primary elements of CT in Knowledge Science research are abstraction and pattern recognition. The other two elements are similar to other elements in different skills. (c) Abstraction optimizes how knowledge science researchers generalize problems and makes a model from this. (d) Pattern recognition focuses on finding the

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similarity among the studies so that the researchers can focus more on dissimilarity factors.

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