User Interface Design of Student's Metacognitive Classification for Adaptive Metacognitive Hypermedia Learning Environment System (HLE)

Qonitatul Hasanah[1]*, Intan Sulistyaningrum Sakkinah[2], Raditya Arief Pratama[3]

{qonitatul@polije.ac.id[1], intan.sakkinah@polije.ac.id[2], radityaariefp@polije.ac.id[3]}

[1,2,3]Department of Information Technology, Politeknik Negeri Jember, Jember, 68101, Indonesia

Abstract. Hypermedia Learning Environment (HLE) is a learning media that uses the concept of multimedia learning and organizes it as an information structure that resembles a network. Adaptive Metacognitive HLE is an HLE that can adapt to the user's persona, i.e., metacognitive abilities. This research designed the HLE system interface for classifying student metacognitive abilities with Unified Modelling Language (UML). The metacognitive abilities of students were integrated with the adaptive HLE, enabling them to gain a heightened awareness of their learning processes, comprehend their strengths and weaknesses, and manage their learning more effectively. This can help improve learning performance, promote problem-solving, and facilitate deeper and more abstract understanding. The result of this research is a system design with Data Flow Diagrams and User Interface design. Further research can evaluate the user experience associated with the implementation of a classification system within the HLE, providing valuable insights into its practicality and effectiveness.

Keywords: Adaptive Hypermedia Learning Environment, user interface design, student classification.

1 Introduction

Education is an integral part of individual and modern societal development. In this digital era, virtual learning systems are becoming increasingly crucial to support the learning process. However, the success of virtual learning implementation is not solely determined by the availability of technology but also by how well the system can adapt to the unique needs and characteristics of each learner. An adaptive learning system is a learning system that presents a personalized and adaptive interface for each user, derived from a variety of behaviors and individual characteristics, along with the user's prior knowledge [1]. However, to achieve effective adaptive learning, three critical elements need attention: (a) technology should be designed and developed by individuals with a theoretical and practical understanding of students, the learning process, and targeted content; (b) the system should provide high interactivity and set high standards for the values it imparts, and (c) the system should have the capability to evaluate learners [2]. In executing an effective learning process, it is crucial for everyone to possess the ability to understand their own metacognition. This involves a deep awareness of how one learns, an understanding of the most effective learning strategies for oneself, and the ability to manage and organize one's cognitive processes reflectively. With

ICoSHIP 2023, November 18-19, Surabaya, Indonesia

DOI 10.4108/eai.18-11-2023.2342547

a strong understanding of metacognition, individuals can efficiently face learning challenges, enhance conceptual understanding, and optimize overall learning outcomes.

To support effective learning activities, every individual must be able to comprehend their own metacognition. Understanding metacognition in the context of learning means training students to develop themselves as self-regulated learners, encouraging them to manage their own learning processes, become assessors of their own thoughts, and actively monitor the ongoing learning process ([3]; [4]). Metacognition essentially creates a close connection between the affective and cognitive dimensions. Empowering metacognition essentially involves integrating the affective and cognitive aspects [5]. Nevertheless, not all students have a profound understanding of metacognition, necessitating the use of an instrument or method to measure or identify the level of metacognition in students.

In previous research, several studies have been conducted to model, predict, and classify students' academic performance using Artificial Neural Network (ANN) methods [6]. Focused on undergraduate students at a university in China, utilizing GPA data as the study object. The results indicated that the ANN's performance could contribute to educational evaluation, achieving a prediction accuracy rate of 84.8% and an AUC value of 0.86. Another study explored the use of Data Mining techniques, such as ANN, Decision Tree, Support Vector Machine (SVM), and Naive Bayes, to predict the performance of new students in supporting university admission decisions. The case study was conducted at the Information System Department, College of Computer and Information Science, Princess Nourah bin Abdulrahman University (PNU), with the research object involving high school GPA averages, Achievement Path Admission Test scores, and General Talent scores. The results showed an ANN accuracy rate of 79.22%, surpassing other methods [7]. Additionally, a study focused on developing a Hypermedia Learning Environment (HLE) with the aim of enhancing students' self-regulated learning (SRL) abilities, using Agile Software Development and Bayesian Network methods. The case study was conducted in the undergraduate programs of Computer Science and Electrical Engineering at Universitas Gadjah Mada, with the research object being self-regulated inventory (SRI) data. The research results indicated that the HLE functioned well, and the system usability scale (SUS) results showed a "good" category with a score of 72.92 [8].

This research aims to implement the Decision Tree algorithm in classifying students' metacognitive abilities as an initial step in developing the Adaptive Metacognitive Hypermedia Learning Environment (HLE). The primary focus of the study lies in designing the user interface (UI/UX) using the Unified Modeling Language (UML) methodology. The research involves a case study with students from the D4 Computer Engineering program at Politeknik Negeri Jember. This interface is intelligently designed to adapt to individual students' levels of understanding, preferences, and needs. By leveraging students' metacognitive understanding, Adaptive Metacognitive HLE can provide a more personalized and effective learning experience, assisting students in identifying appropriate learning strategies and enhancing their understanding and learning motivation. Thus, this research integrates metacognitive elements into Adaptive Metacognitive HLE, forming a robust foundation for the development of an adaptive and responsive learning environment.

2 Material and Methods

2.1. **Hypermedia Learning Environment System (HLE)**

The Hypermedia Learning Environment (HLE) is an instructional medium that employs the concept of multimedia learning and organizes it as an information structure resembling a network [9]. In this structure, information fragments are stored in interconnected nodes and can be accessed through electronic hyperlinks [10].

In the modern era, students still rely on educators. Students require a flexible learning environment that provides possibilities for content and knowledge arrangement, as well as control over their learning. Currently, multimedia and hypermedia technologies can realize adaptation and personalization to meet each student's learning preferences [11]. The implementation of key cognitive and metacognitive regulatory processes is crucial for enhancing learning in open learning environments like hypermedia [12]. The results can lay the groundwork for developing an adaptive system with a dynamic model, considering individual differences among students [13].

2.2. **Metacognitive**

Metacognition is the individual's ability to understand and regulate their own thinking. Individual metacognitive support significantly influences online students' metacognitive performance, while social metacognitive support enhances students' engagement in peer learning processes and enables collaboration in Computer-Supported Collaborative Learning (CSCL) [14].

Metacognition consists of two interrelated aspects, as illustrated in **Figure 1**. Knowledge of metacognition and regulation of metacognition are the two main facets of metacognitive abilities. Knowledge of metacognition is associated with understanding, whereas regulation of metacognition involves the ability to self-regulate by utilizing that knowledge to achieve learning goals. These two aspects are interrelated and essential for attaining effective metacognitive abilities [15].

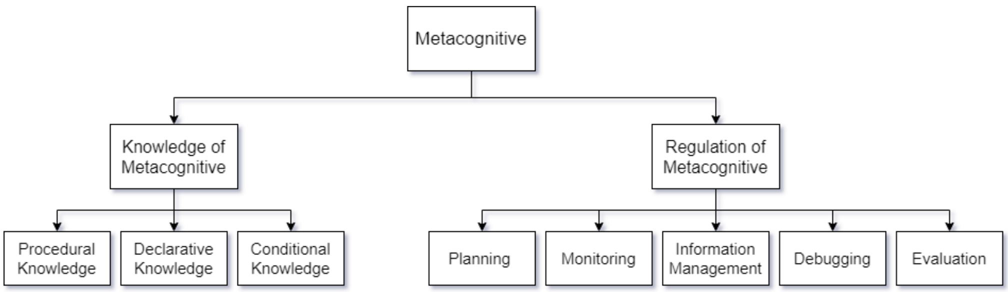

Fig. 1. Metacognitive Component [15]

2.3. Unified Modelling Language (UML)

The use of the Unified Modelling Language (UML) in this research involved a series of crucial stages that supported the modelling [16] of the Adaptive Metacognitive Hypermedia Learning Environment (HLE) system and the integration of students' metacognitive abilities. The primary focus of this research is the development of the HLE interface, designed with a deep consideration of students' metacognitive abilities. Through the application of the Unified Modelling Language (UML), the stages of analysis, design, and development of the Adaptive Metacognitive HLE interface were centred on creating an adaptive and responsive learning environment.

In the integration of students' metacognitive abilities, UML was used to model the interaction between students and the system, understand the workflow in the metacognitive context, and produce an interface that supports monitoring and enhancing students' metacognitive abilities. Thus, the UML approach formed a robust foundation in the development of Adaptive Metacognitive HLE that understood and responded to individual metacognitive needs, shaping a more personalized and effective learning environment.

2.4. Data Flow Diagram

The development of the Adaptive Metacognitive Hypermedia Learning Environment (HLE) interface was undertaken with careful consideration of students' metacognitive abilities, utilizing Data Flow Diagrams (DFD). The DFD approach was employed to illustrate the data flow within Adaptive Metacognitive HLE, map out the processes, and identify the entities involved in integrating students' metacognitive abilities. With the assistance of DFD, the stages of analysis, design, and development [17] of the Adaptive Metacognitive HLE interface were focused on modelling a system capable of understanding and responding to individual metacognitive needs. The result was an interface that supported monitoring and enhancing students' metacognitive abilities, making Adaptive Metacognitive HLE a more effective and adaptive personalized learning environment.

3 Results and Discussions

The Adaptive Metacognitive Hypermedia Learning Environment (HLE) system serves as the primary foundation for an effective digital learning experience. HLE is designed to provide students with easy and structured access to educational content, facilitating information delivery, content organization, and interactive support such as assignments and assessments. The User Interface (UI) in HLE plays a crucial role in connecting students with learning content. A well-designed UI in HLE should be carefully considered, incorporating an easily understandable layout, intuitive navigation, and aesthetics that support focused learning. Users should be able to quickly access the content they need without hindrances, and interactive features like discussions or collaborations should be seamlessly integrated. A good UI in HLE creates a more enjoyable and productive learning experience for students.

In the context of HLE, Use Case Diagrams are used to depict various roles or actors within the system, including super admin, admin, and students. The super admin has high-level access to manage the entire system, the admin is responsible for content administration and management, while students are end-users who interact with the learning materials. Use Case Diagrams help understand how each actor interacts with the system and how functionalities operate.

Furthermore, the Data Flow Diagram (DFD) in HLE is an essential tool for modelling data flow within the system. DFDs at different levels, such as level 0, level 1, and so on, help break down how data flows between entities in HLE. DFDs allow us to identify processes, external entities, and data involved in HLE. This is a crucial initial step in designing an efficient system and ensuring that data flows within HLE operate smoothly.

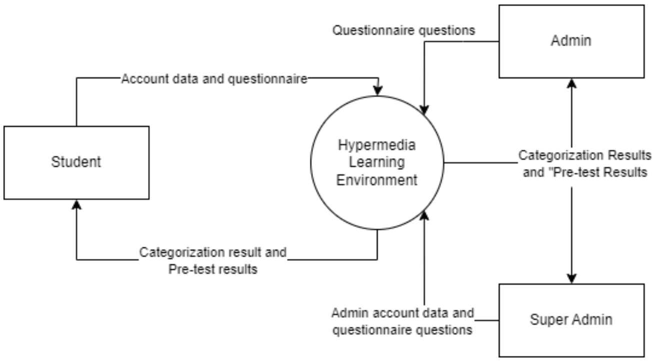

Fig. 2. Data Flow Diagram Level 0

Figure 2 illustrates the Data Flow Diagram Level 0 of the Hypermedia Learning Environment, featuring three access levels: students, administrators, and super administrators. Students have the capability to receive categorization results and pre-test scores from the HLE, while also contributing through account data and questionnaires. Administrators possess access to student outputs and the ability to input questionnaire questions. Super administrators, with additional privileges, are empowered to manage admin account data alongside their other responsibilities.

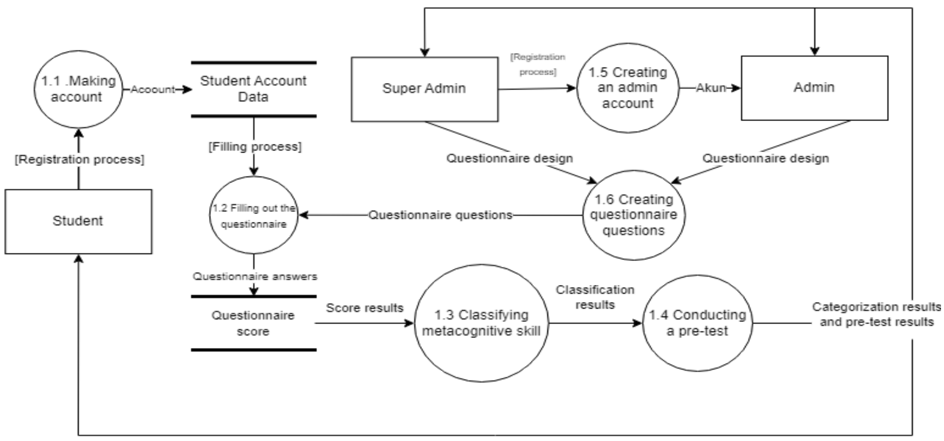

Fig. 3. Data Flow Diagram Level 1

Figure 3 shows students go through a registration process, creating an account initially, and once the account is established, the data is stored in the student account database. Students listed in the database can complete questionnaires by submitting their answers. The questionnaire results, in the form of scores, are categorized based on metacognitive. After categorization, students can take a pre-test. The categorization results and pre-test scores are accessible to students, administrators, and super administrators. Super administrators and administrators begin by registering admin accounts. Once the admin accounts are created, administrators and super administrators collaboratively design questions to form questionnaires, which are then made available for students to fill out.

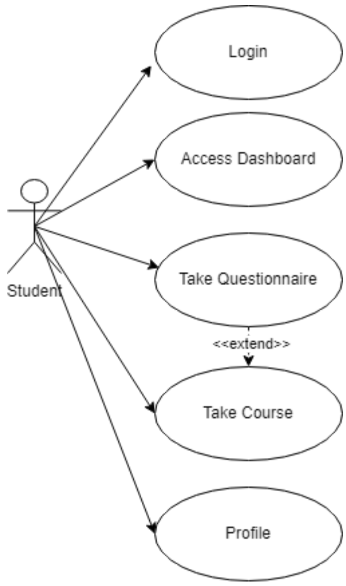

Fig. 4. Use Case Diagram

Figure 4 shows the use case diagram of HLE for the classification of metacognitive skills. There are 5 main use cases namely, login, dashboard, questionnaire, course, and profile. Student can only take a course after he takes the questionnaire. The course instructions will adjust with the metacognitive skill level.

The utilization of Data Flow Diagrams (DFD) and Hypermedia Learning Environment (HLE) in this study provides significant advantages. DFD aids in system design by visualizing data flow and processes, offering a clear understanding of how data circulates within the Hypermedia Learning Environment. It establishes access levels for students, administrators, and super administrators, ensuring appropriate access rights for each role. Additionally, insights into the student registration process and data storage within HLE guarantee well-structured procedures. The integration of Use Case Diagrams facilitates comprehension of user-system interactions, while a focus on UI/UX, considering metacognitive aspects in HLE, ensures user interface development aligned with user needs. Integrating metacognition into the Adaptive Metacognitive HLE forms a robust foundation for personalized and adaptive learning. This empowers students to identify suitable learning strategies based on their learning styles and metacognitive needs. Therefore, the combined use of DFD and HLE supports the development of a structured learning environment, ensuring the effectiveness of learning by incorporating metacognitive aspects.

High-Fidelity HLE is a development stage that focuses on the UI visual design. In this process, tools like Figma are used to create the final appearance of the HLE interface. This design includes colour selection, typography, icons, and other UI elements. High Fidelity HLE aims to provide an attractive and functional look for the previously designed interface in **Figures 5, 6, 7,** and **8**, it shows the Dashboard Page, Questionnaire Page Layout, Virtual Agent Page, and User Profile Page. It helps visualize the actual user experience within HLE. In the overall context of HLE development, these elements work together to create an effective and satisfying digital learning environment, better supporting the student's learning journey.

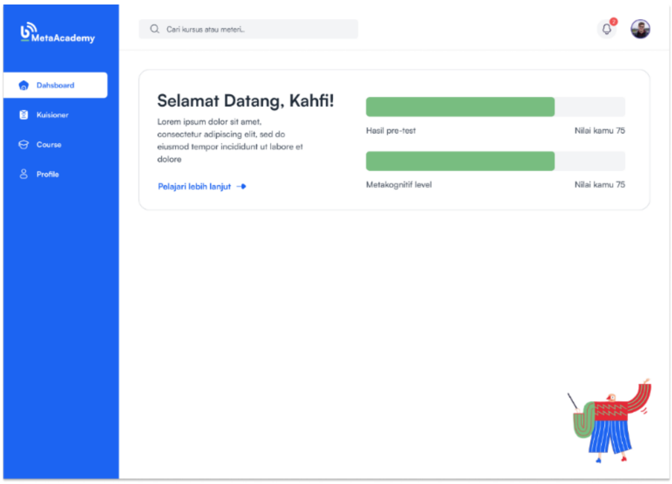

Fig. 5. Dashboard Page

Figure 5 shows the dashboard page of HLE. The dashboard page shows the information about the level of student metacognitive skills. On the dashboard page, if the student has not taken the questionnaire, then the virtual agent will guide students to take the questionnaire first to get the classification of metacognitive skills.

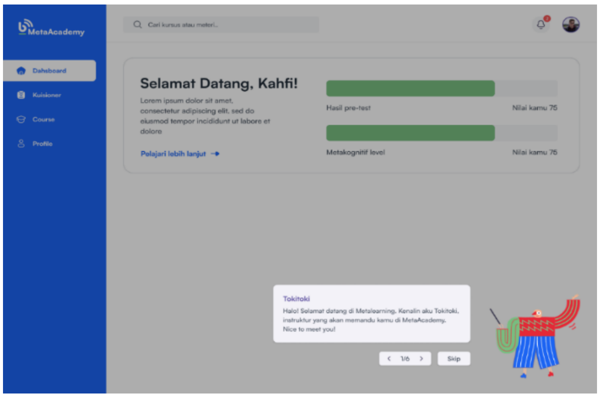

Fig. 6. Virtual Agent

Figure 6 shows how the virtual agent welcomes and guides the students to take the questionnaire. The virtual agent will give the instructions to take the questionnaire first to get the metacognitive skill classification.

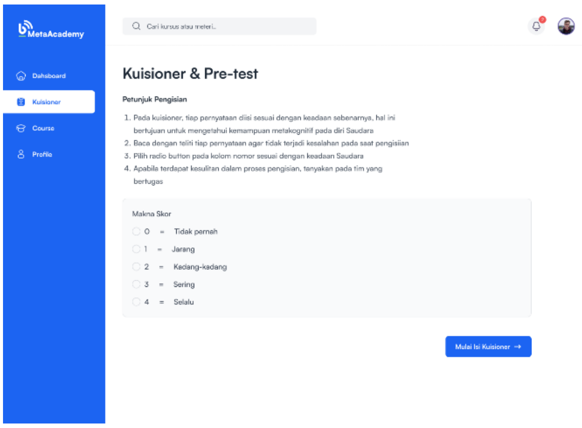

Fig. 7. Questionnaire Page Layout

Figure 7 shows the questionnaire page. This page shows the instructions on how to fill out the questionnaire using a Likert scale from 0 to 4. The questionnaire page shows 52 questions to classify the student's metacognitive skill according to the Metacognitive Awareness Inventory. These questions are divided into 2 main categories, namely, knowledge of metacognition (KM) and regulation of metacognition (RM). Knowledge of metacognition is related to knowledge, while regulation of metacognition is related to the ability to self-regulate in utilizing this knowledge to achieve learning goals. These two aspects are interrelated and necessary to achieve effective metacognitive abilities [18].

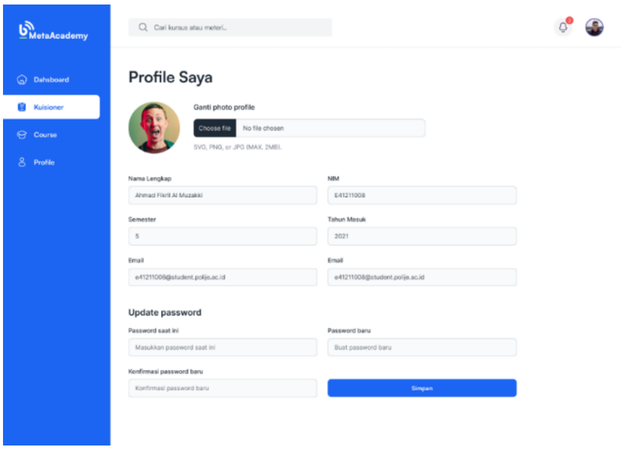

Fig. 8. User Profile Page

Figure 8 shows the user profile page. This page allows user to complete their identity. User identity will be used to analyse the number of users based on the generation and metacognitive level.

The findings of this study contribute significantly to the body of knowledge in the field. The results, derived from the implementation of Data Flow Diagrams (DFD) and the Hypermedia Learning Environment (HLE), offer valuable insights into the structured design of a learning environment. The identified access levels for students, administrators, and super administrators, as visualized in the DFD, provide a nuanced understanding of user roles and their corresponding privileges. Furthermore, the detailed depiction of student registration processes and data storage within HLE adds depth to the understanding of system functionalities. In the broader context, these findings align with the need for well-organized and user-specific educational interfaces. Importantly, the study's emphasis on integrating metacognitive elements into the Adaptive Metacognitive HLE establishes a novel contribution. This innovative approach not only addresses the personalized learning needs of students but also aligns with the current discourse on metacognitive strategies in educational technology. The study's findings resonate with and build upon previous research in the area, reinforcing the importance of considering metacognition in the design of educational technologies. As such, this research enriches the existing body of knowledge by providing practical insights and implications for the effective integration of metacognitive elements into adaptive learning environments.

4 Conclusion

This study highlights the importance of employing Data Flow Diagrams (DFD) and the Hypermedia Learning Environment (HLE) in the development of a structured and user-centric educational platform. The delineation of access levels through DFD provides nuanced insights into user roles, and tailoring privileges for students, administrators, and super administrators. The in-depth exploration of student registration processes and data storage within the HLE contributes valuable insights into system functionalities, emphasizing the need for well-organized educational interfaces. Notably, the innovative integration of metacognitive elements into the Adaptive Metacognitive HLE in the study represents a significant advancement, aligning with the evolving discourse on personalized learning strategies. These findings not only enrich the existing body of knowledge in educational technology but also offer practical insights for enhancing the effectiveness of adaptive learning environments. To extend this research, it is recommended that future studies delve into implementing UI/UX design into a web-based system. This step would ensure an optimal user experience, fostering seamless interaction and potentially improving educational outcomes. Such investigations could further advance the field by addressing specific challenges and opportunities associated with web-based educational platforms.

Acknowledgments

The successful completion of this research has been made possible through the generous funding provided by Politeknik Negeri Jember. We extend our sincere gratitude for the financial support received through the PNBP (*Penerimaan Negara Bukan Pajak*/ Non-Tax Revenue) scheme with an affirmative focus. This funding has played a pivotal role in enabling the research endeavours and has significantly contributed to the realization of our study. We express our appreciation for the commitment and support from Politeknik Negeri Jember, which has greatly facilitated the advancement of knowledge in the field.

References

[1] B. Steichen, H. Ashman, and V. Wade, “A comparative survey of personalised information retrieval and adaptive hypermedia techniques,” *Inf Process Manag*, vol. 48, no. 4, pp. 698–724 (2012).

[2] V. Aleven, “A is for Adaptivity, But What is Adaptivity? Re-Defining the Field of AIED.,” in *AIED Workshops* (2015).

[3] P. D. Eggen and D. P. Kauchak, “Educational psychology: Windows on classrooms,” *(No Title)* (2007).

[4] M. Peters, “Does constructivist epistemology have a place in nurse education?” *Journal of nursing education*, vol. 39, no. 4, pp. 166–172 (2000).

[5] A. Learning, “Focus on inquiry: A teacher’s guide to implementing inquiry-based learning,” (2004).

[6] E. T. Lau, L. Sun, and Q. Yang, “Modelling, prediction and classification of student academic performance using artificial neural networks,” *SN Appl Sci*, vol. 1, pp. 1–10, (2019).

[7] H. A. Mengash, “Using data mining techniques to predict student performance to support decision making in university admission systems,” *Ieee Access*, vol. 8, pp. 55462–55470 (2020).

[8] I. S. Sakkinah, R. Hartanto, and A. E. Permanasari, “Hypermedia Learning Environment Development to Enhance Self-Regulated Learning Based on Self-Monitoring Skills,” *Jurnal Nasional Teknik Elektro dan Teknologi Informasi*|, vol. 11, no. 02, pp. 97–103 (2022).

[9] I. S. Sakkinah, R. Hartanto, and A. E. Permanasari, “Hypermedia Learning Environment Development to Enhance Self-Regulated Learning Based on Self-Monitoring Skills,” *Jurnal Nasional Teknik Elektro dan Teknologi Informasi| Vol*, vol. 11, no. 2 (2022).

[10] P. Gerjets and P. Kirschner, “Learning from Multimedia and Hypermedia BT - Technology-Enhanced Learning: Principles and Products,” N. Balacheff, S. Ludvigsen, T. de

Jong, A. Lazonder, and S. Barnes, Eds., Dordrecht: Springer Netherlands, pp. 251–272. doi: 10.1007/978-1-4020-9827-7_15 (2009).

[11] M. Ivanova, C. Holotescu, and G. Grosseck, “Multimedia, Hypermedia, and Transmedia in Support of Learning,” in *2014 Eighth International Conference on Complex, Intelligent and Software Intensive Systems*, pp. 504–509, (2014).

[12] A. Roger, A. Witherspoon, A. Chauncey, C. Burkett, and A. Fike, “MetaTutor: A MetaCognitive tool for enhancing self-regulated learning,” *AAAI Fall Symposium - Technical Report*, pp. 14–19, Jan. (2009).

[13] A. Çebi and T. Güyer, “Modeling of relationships between students’ navigational behavior and problems in hypermedia learning system: the moderating role of working memory capacity,” *Interactive Learning Environments*, vol. 30, no. 3, pp. 552–567, (2022).

[14] M. Zion, I. Adler, and Z. Mevarech, “The Effect of Individual and Social Metacognitive Support on Students’ Metacognitive Performances in an Online Discussion,” *Journal of Educational Computing Research*, vol. 52, no. 1, pp. 50–87, (2015).

[15] S. Sánchez-Alonso and Y. Vovides, “Integration of metacognitive skills in the design of learning objects,” *Computers in Human Behavior*, vol. 23, no. 6, pp. 2585–2595, (2007).

[16] J. Rumbaugh, *OMT Insights: Perspective on Modeling from the Journal of Object-Oriented Programming*, vol. 6. Cambridge University Press (1996).

[17] A. A. A. Jilani, M. Usman, and A. Nadeem, “Comparative study on DFD to UML diagrams transformations,” (2011).

[18] S. Sanchez-Alonso and Y. Vovides, “Integration of metacognitive skills in the design of learning objects,” *Computers in Human Behavior*, vol. 23, pp. 2585–2595 (2007)