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A Comprehensive Design Guide to Adaptive e-Learning System Based on VARK Learning Styles

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ABSTRACT

An adaptive e-learning system is a system that caters to the needs of learners such as their learning style and knowledge. The adaptive e-learning system has been proven to improve the outcomes of learners and increase their motivation to learn. Several techniques could be used to create an adaptive e-learning system, one of them is adjusting the materials according to learners' learning style. VARK Learning style is one of the learning styles that is fitted to be applied to adaptive e-learning systems and help learners understand how they learn better. To make an adaptive e-learning system based on VARK learning styles, there are several things to be noted. An adaptive e-learning system has three main components consisting of learner model, domain model, and adaptation model. Since the VARK learning style is flexible, it could be adjusted according to the study materials when needed by combining one style with another to create a combined style suited to the study materials. A multimodal mode is also needed to fully cater to the needs of learners who have more than one learning style. This can be done by providing them with features representing each of the main four VARK learning styles and letting the learners choose the needed features. This paper emphasizes the main foundation of an adaptive e-learning system and the needs of multimodal features in it, including a design framework to help get a better understanding of designing an adaptive e-learning system for learning applications.

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1. INTRODUCTION

An adaptive e-learning system can be defined simply as a system that adapts to the learning needs of learners such as their capabilities and preferences. Some research done by [El-Sabagh \(2021\)](#) and [Wu et al., \(2018\)](#) state adaptive e-learning systems are effective in improving learning outcomes, reducing the time and effort required to understand the materials, and especially increasing student engagement. Making this reason the main function and purpose of adaptive e-learning systems. Additionally, adaptive e-learning systems can offer several benefits compared to traditional e-learning systems, based on El-Sabagh's research proved that adaptive e-learning offers a higher learner satisfaction and the learners' learning outcome is better than traditional e-learning systems ([El-Sabagh, 2021](#)). These benefits are particularly crucial in today's digital age, where online learning has become common in education where learners come from diverse backgrounds, skill levels, and learning preferences.

To start making an adaptive e-learning system there are several techniques to use such as using artificial intelligence and algorithms, and another way is to adjust the content of learning materials according to the needs of the learners for example according to their learning style or learning preferences (adaptation target is the learning material) ([Ennouamani & Mahani, 2017](#)). Learning preferences are usually developed naturally based on an individual habit or by using the learning models available. Learning style in general can be simplified as the unique way in which an individual learns and processes information. Usually, learning style is most used during an independent study (or self-learning) instead of in class, considering how most schools still use the same learning approach for all students ([Boland & Amonoo, 2021](#); [El-Sabagh, 2021](#); [Lwande et al., 2021](#); [Tanamir et al., 2020](#)). Individuals who take the initiative to do self-learning tend to learn more than those waiting to be explained by their teachers. To make a learner's self-learning process more effective, an individual first needs to understand their way of learning.

Many learning styles are available for students, such as Kolb's learning model, Felder-Silvermann, Honey and Mumford, Dunn and Dunn, dan VARK. Among the many available learning styles, one of the popular models is VARK, which in short stands for Visual, Auditory, Reading/Writing, and Kinesthetic. VARK categorizes learners into four groups based on their names. VARK has proved to be effective in enhancing the learning experience for learners because of its flexibility and ease of finding study sources ([Boland & Amonoo, 2021](#); [Rao & Arunachalam, 2021](#)). This is one of the reasons why VARK is suited to be applied to an adaptive e-learning system.

This literature review will delve into the development of adaptive e-learning systems and the critical elements that need to be considered included in the system. The review will explore the importance of learning styles in e-learning and the potential benefits of incorporating the VARK model into an adaptive e-learning system. This review aims to provide valuable insights and guidelines as a framework for making an effective adaptive e-learning system by synthesizing and analyzing the existing literature on these topics.

2. METHODS

The literature review approach is employed in this article to analyze and incorporate insights from existing literature and previous research on adaptive e-learning systems based on VARK learning styles. This process serves as a reference to acquire the latest insights and understanding of adaptive e-learning systems. The literature was reviewed according to their focus and strength. The accumulated insights and information were then analyzed to produce

a design framework that serves as guidelines for future research in adaptive e-learning systems and practical application in the design of adaptive e-learning platforms.

3. RESULTS AND DISCUSSION

3.1. Foundational Structure of Adaptive e-Learning System

The growth of adaptive e-learning systems can be said originated in the 1990s (Ennouamani & Mahani, 2017) when hypertext and user modeling made significant advancements to adapt the system behavior to the users. Thus, changing the foundation way of learning from a one-size-fits-all approach to a more personalized approach to increase the learner's potential by tailoring the materials to the needs of the learners and letting them understand their current knowledge and skills level (Katsaris & Vidakis, 2021; Terzieva & Rahnev, 2018). The rapid advancement of technology helps adaptive e-learning systems grow even more using the help of online technology in teaching whenever and wherever learners need (including giving real-time feedback), interactive media, programming techniques, and artificial intelligence. Not only that, as e-learning system, an adaptive e-learning system could be built into various devices such as computers, tablets, and even smartphones making it accessible for everyone as long as they are connected online since one of the criteria of an e-learning system can be delivered to learners' devices online (Ennouamani & Mahani, 2017; Katsaris & Vidakis, 2021). To start developing an adaptive e-learning system there are several key findings must be incorporated into the design of an adaptive e-learning system to further optimize it.

3.2. Components of Adaptive e-Learning System

From Ennouamani and Mahani (2017), an adaptive e-learning system has three main components that also align with El-Sabagh (2021) which used a similar foundation. They made an architecture diagram for the three main components to make it easier to understand (see Figure 1).

As shown in Figure 1, the components that should be included in an adaptive e-learning system such as:

- (i) Learner Model. This is an essential part of the adaptive e-learning system. It serves as the learners' characteristics representation, covering a wide range of factors that contribute to the learners' distinctive learning profile. These factors may include learning styles, reasoning styles, experiences, physical skills, emotions, needs, habits, motivation, culture, personality, interests, cognitive styles, and social context.
- (ii) Domain Model. Serves as a structured representation of information or knowledge to help understand a specific topic or subject. It can be thought of as a concept of a specific case study.
- (iii) Adaptation Model. The adaptation model connects learners and the (learning) materials by incorporating the learners' needs (including their characteristics) with the content. It has rules and functions that can help to deliver the right content materials and how the learners receive them according to their needs.

Based on Ennouamani and Mahani (2017) the adaptive e-learning system could be divided into three approaches as follows.

- (i) Macro-Adaptive Approach. This approach focused on the progress of the learners at their own pace because every learner has capabilities that differ from one another. This approach considers several factors such as their goals, preferences, cognitive capabilities, motivation, personality, experiences, and achievement. This approach follows the basics

for example presenting the materials, giving examples, Q&A (question and answers), and providing assessment for their study.

- (ii) Aptitude-Treatment Interaction (ATI) Approach. This approach focused on the learner’s ability to control their learning process. It can be total control over their studies or only a partial amount. It is recommended to limit the control for students with a limited prior understanding of the content material. There are three levels of control such as complete independence over their studies, partial control within specific tasks, and fixed tasks with regulated pacing.
- (iii) Micro-Adaptive Approach. This approach can identify the learners’ requirements to help deliver the best learning experience for them. In contrast to the macro-adaptive approach, this approach considers specific and real-time information about the learner within the system by analyzing and tracking the learner's actions and responses.

Several factors are considered for this approach such as motivation, learner errors, emotional state, and more. This approach has 2 main components:

- (i) Diagnostic process (identifies the learner’s traits).
- (ii) Optimization Process (optimizing the learners’ interactions between the content materials and the system environments)

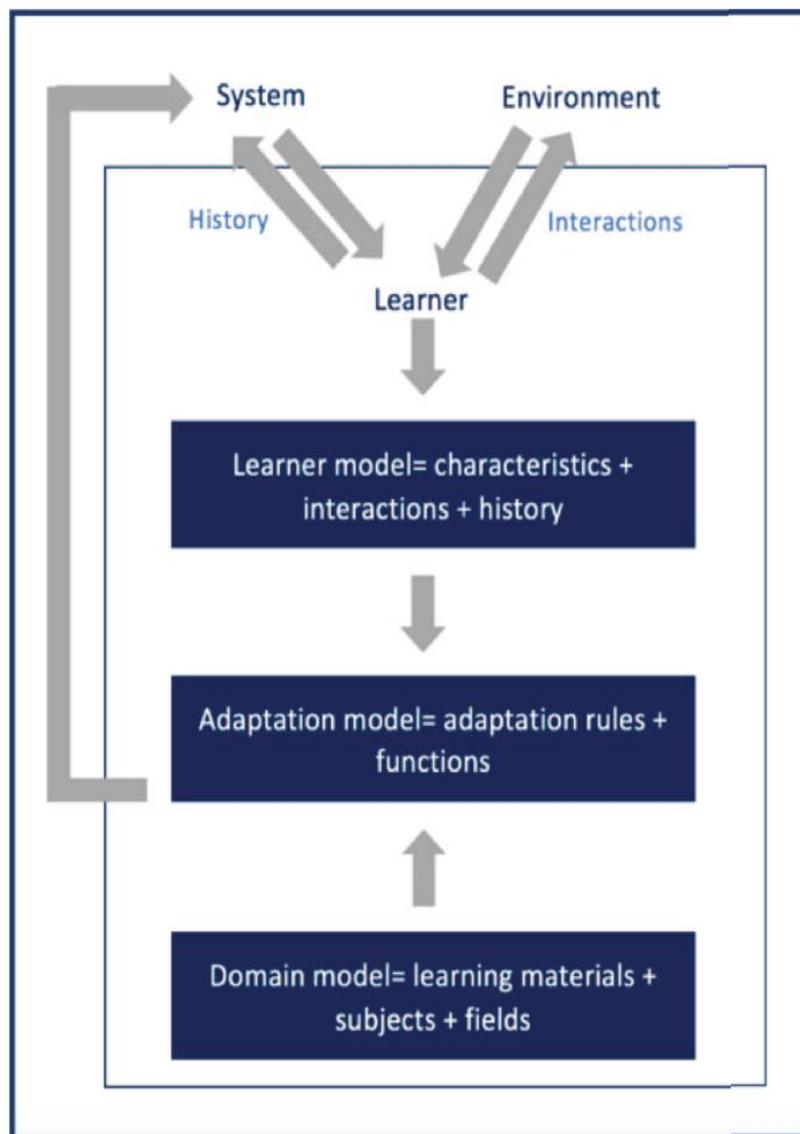


Figure 1. The architecture of Adaptive e-Learning System (Ennouamani & Mahani, 2017).

3.3. Developing Adaptive e-Learning System Procedures

The initial steps involved to start developing an adaptive e-learning system from the literature share some similarities. El-Sabagh (2021) research has provided a design method that they used for their adaptive e-learning which is the ADDIE method. This can be used as a foundation for designers when developing an adaptive e-learning system for learning applications. The ADDIE method consists of analyze phase, design phase, development phase, implementation phase, and evaluation phase. This is also similar to the research Kusworo *et al.* (2021) using the research and development mode. The explanation is in the following:

- (i) Analyze Phase. During this phase, the first thing to do to is to gather the main components of adaptive e-learning systems such as student's needs and characteristics, available resources, and desired course outcomes. This information could be obtained through various methods such as interviews, literature studies, or questionnaires. After the information needed is complete, set an instructional framework for the adaptive e-learning system.
- (ii) Design Phase. The next step is the design stage. Designers need to first identify the overall goal of the learning objective and then break it down based on different approaches. This is followed by making an assessment tool needed to measure students' capabilities, progress, and learning styles. Additionally, adaptive e-learning strategies are also needed to cater to their needs.
- (iii) Development Phase. The development phase focuses mostly on the creation of an adaptive e-learning system prototype based on VARK learning styles.
- (iv) Implementation Phase. Implementing the adaptive e-learning system prototype to the target and receiving feedback.
- (v) Evaluation Phase. Taking evaluation from the user test/experiment.

3.4. The VARK Learning Styles for Adaptive e-Learning System

Learning style plays an important role in an adaptive e-learning system as it helps to tailor the needs of the learners by catering to their individual preferences in learning. These styles can vary from one individual to another and indicate how the learner tries to observe the materials, interacts with the materials, and how learner tries to answer them. In short, it's how learners try to process and understand their learning materials in their way (Lwande *et al.*, 2021). As stated before, there are many learning styles available that can be applied to an adaptive e-learning system and one of them being the VARK learning style (Figure 2).

VARK learning style is a learning style developed by Neil Fleming in 1992 and consists of four categories involving a person's physiological characteristics as shown in Figure 2. It helps students know what learning styles are suited for them by answering the questionnaires that could be found on the internet (Martin *et al.*, 2021; Raj & Vidyaathulasiraman, 2021).

- (i) Visual - This type of learner prefers to be provided with visual materials because they mainly depend on their visual sense. Such as images, videos, mind maps, and other visual-related material. They usually aren't distracted by noises but by surrounding movements.
- (ii) Auditory (Aural) - This type of learner receives information better through their ears making them prefer to learn by listening from example recorded notes or materials and group discussions. They tend to be distracted by noises and are usually sensitive towards words.
- (iii) Read/Write - The read/write learner usually prefers to take notes to remember the materials and learn from the text. Such as PowerPoint, written assignments, PDFs, and text-based material.

Kinesthetic - This type of learner receives and understands information better when doing it hands-on. It is recommended to provide them with hands-on materials, demonstrations, practical exercises, and case studies to help them learn.

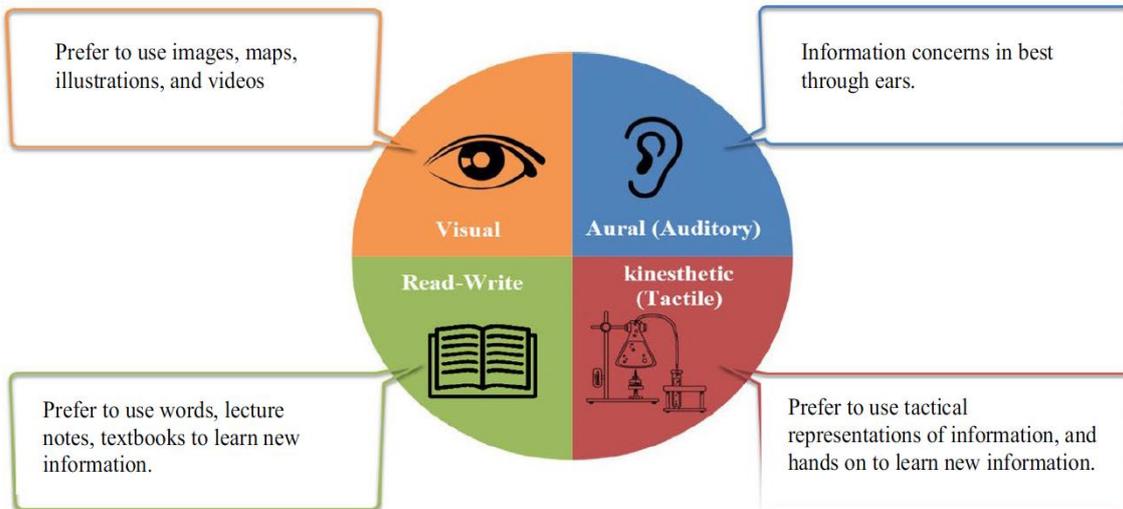


Figure 2. VARK Learning Styles Categories (El-Sabagh, 2021).

3.5. VARK in Different Media

The VARK learning style is mainly focused on the sensory-perceptual media (Mahmood *et al.*, 2023) making it suited applied to interactive-based media as it allows the opportunity to combine various modalities. By integrating the learning styles into multimedia, the learning could be done through interactive simulations, virtual reality, and gamified activities, stimulating their senses simultaneously.

In traditional approaches, the VARK learning style could be applied in class or self-learning for example, visual learners can learn by utilizing a visual-based textbook during lectures, using highlighters for their notes, posters, diagrams, flowcharts, and making mind maps. Auditory learners can benefit from class discussions where students can interact with teachers and converse with their classmates. Read/write learners can learn from handouts, articles, a variety of textbooks, dictionaries, quotations, and written exercises. While kinesthetic learners can benefit from experiments in class or lab, real-life, and hands-on activities in the classroom (see <https://www.unb.ca/fredericton/cetl/services/teaching-tips/course-delivery/student-learning-styles.html>).

3.6. Elements and Features of an Adaptive e-Learning System Based on VARK Learning Styles

To develop an adaptive e-learning system based on a learning style (in this case VARK learning styles), it is allowed to adjust the VARK learning styles to align with the materials used for the case study rather than including all the VARK learning styles. The VARK learning style is modified to suit engineering students who primarily rely on visual materials. The system combines the original three learning styles (read/write, auditory, and kinesthetic) with the visual learning style, resulting in the creation of three main modules:

- (i) Narrative module: Combining the visual and read/write learning styles, presenting the materials with a combination of pictures and text.
- (ii) Pseudocode module: Combining the visual and aural learning styles, the material is presented as a video with audio and visual elements.

(iii) Code module: Combining the visual and kinesthetic learning styles, this module encircles actual Java code and practical examples.

Several features and user flow for the adaptive e-learning system are mostly similarly designed according to the literature. Some key steps taken by the user are as follows and can be concluded as seen in **Figure 3** (El-Sabagh, 2021; Kusworo *et al.*, 2021; Nugraha & Budiyo, 2022).

- (i) Students begin by taking a VARK test to identify their preferred learning styles. The VARK test could be modified according to the needs.
- (ii) A pre-test can be administered to assess students' existing knowledge and understanding. Though it is not mandatory to add a pre-test, this can help the system to adapt even better to the learner during their study process.
- (iii) Based on their learning styles, students are provided with materials tailored to their preferences. These materials include exercises to quantify their comprehension.
- (iv) To evaluate their understanding further, students undergo another test, which consists of different questions compared to the previous step.

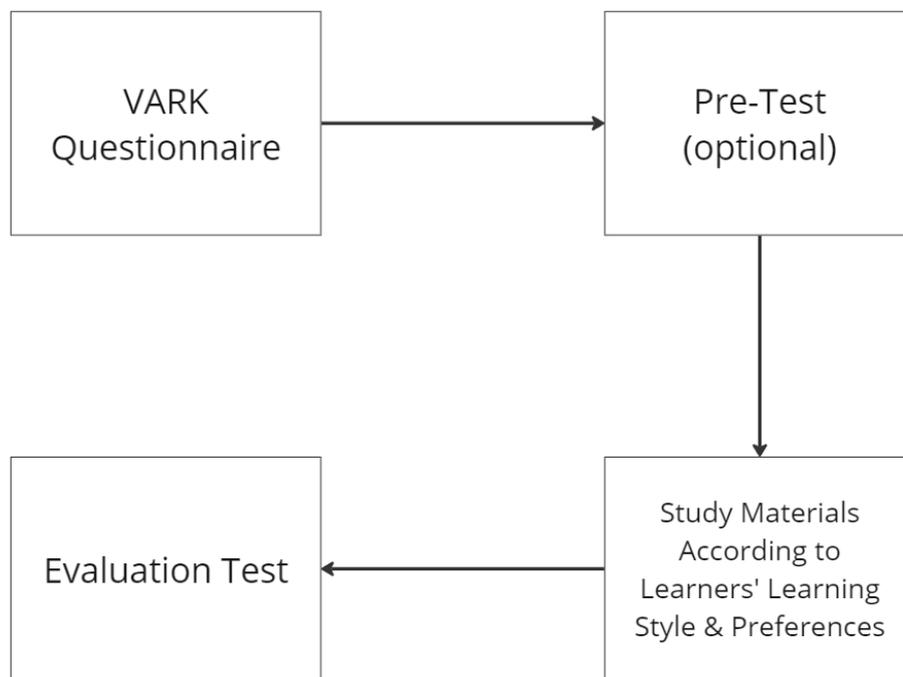


Figure 3. Adaptive e-Learning System User Flow.

While the rest of the process is mostly the same, the adaptive e-learning system designed by Nugraha and Budiyo (2022) introduces three user modes: students, lecturer/teacher, and administrator. Each user has a role and specific access to the adaptive e-learning system as seen in **Figure 4**.

The system includes:

- (i) Students (login, VARK Questionnaire, study materials, logout). Here students can interact with interactive study materials with personalized content (based on their learning styles)
- (ii) Lecturer/Teacher (login, study materials input & managing, data testing classification, logout). Teachers are in charge of managing and monitoring student performance, creating and assigning study materials, and providing feedback to the students.

(iii) Administrator (login, data training input, data set labeling, data set pre-processing, logout). Administrators have the authority to oversee the overall adaptive e-learning systems and classify the materials according to the learning style.

Some of the adaptive e-learning systems from the literature above mostly haven't included an exercise feature, it is highly recommended to consider integrating an exercise feature to help students gain a better understanding of the subject and increase the engagement between students and the learning materials. These exercises can be quizzes, interactive case studies, simulations, or hands-on activities depending on the subject.

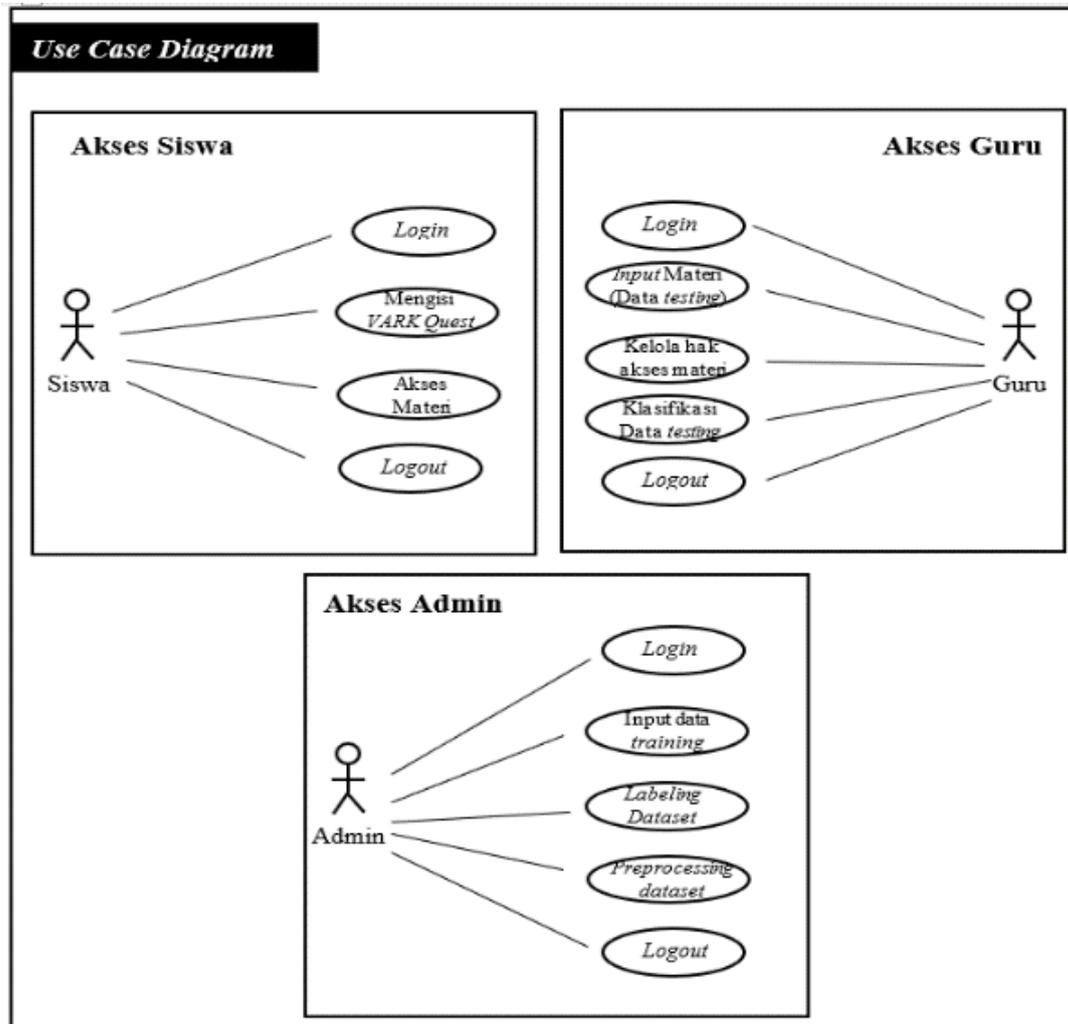


Figure 4. Use Case Diagram of Adaptive e-Learning System (Nugraha & Budiyanto, 2022).

3.7. Addition of Multimodal Mode and Features

Most of the literature provides an excellent result but most of them don't consider the need for a multimodal mode for the system. To fully cater to the diverse learning needs of students, it is crucial to incorporate multimodal features in an adaptive e-learning system. People in general cannot be easily categorized into one specific learning style, as each person has their own unique set of preferences and needs.

As stated before, the VARK learning style is very flexible which means a learner isn't bound to one learning style only. After taking the VARK questionnaire, there is a huge possibility that a learner will get a multimodal result which means that the learner can choose any learning methods they want which is why the multimodal mode serves as an important feature. The feature could be a customized one where learners can choose the key features they want to

add when learning (for example if they need a video-based explanation, they can use it, and if they only need a PDF summary of study materials they can have it without the need to use other features) By providing a range of modalities such as visual, auditory, read/write, and kinesthetics, students can engage with the material in a way that is most effective for them. This is the core of adaptive e-learning, as it aims to provide personalized learning experiences to each user. By integrating multimodal modes, adaptive e-learning systems can enhance their effectiveness and promote a better-personalized learning process.

From the literature above, a new design framework can be developed for designing an effective adaptive e-learning system. This framework will include the multimodal mode to cater to the needs of multimodal students and let them choose the feature that they need. The proposed framework will serve as a guide for designers and developers in creating adaptive e-learning systems that can improve students' learning outcomes and experiences. The framework is shown in **Figure 5**.

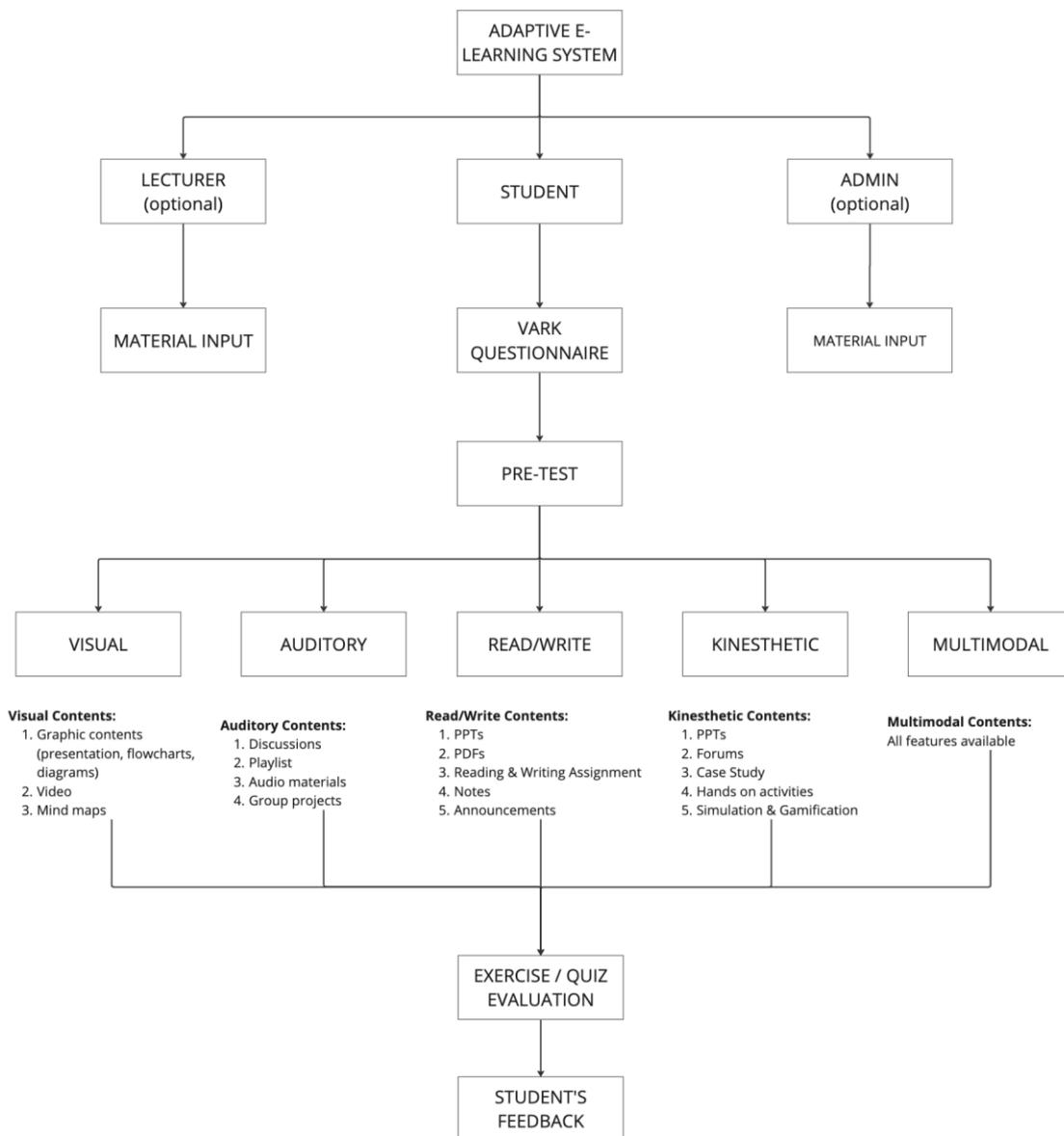


Figure 5. Adaptive e-Learning System Design Framework Guide.

To create a successful adaptive e-learning system, the key focus is on the students, while the lecturer and admin play a more supporting role by anticipating the students' potential needs and providing study materials tailored to their preferences along with upcoming feedback. The initial steps included taking the VARK questionnaire to help students identify their most effective learning styles. Additionally, it is highly recommended to conduct a pre-test after the questionnaire to assess students' current knowledge and comprehension level. This information is crucial as it enables adjustments to be made to the learning material and level to ensure an optimal learning experience for them. The implementation of the pre-test is optional to be used in a design prototype or development stage if the study material has yet to be decided.

Next, students can start the learning process based on their identified learning styles using the features or content recommended in **Figure 5** including the multimodal mode that encompasses features from all four main VARK learning styles. To avoid overwhelming the students, it is advisable to limit the feature selection. After completing the learning process, students can be directed to take another test or quiz to evaluate their knowledge and assess the compatibility of their current learning style. If necessary, students can switch to a different learning style that suits them better.

Finally, students are encouraged to provide feedback on the adaptive e-learning system, to understand their thoughts on learning experiences and additional features they would like to be included. This feedback will help in refining and improving the adaptive e-learning system to better cater to their needs.

4. CONCLUSION

By acknowledging and catering to the diverse learning preferences of learners. The adaptive e-learning system is opening up opportunities in the education field and the incorporation of the VARK learning styles increases a promising result in the future. By tailoring the contents to their needs, the adaptive e-learning system can provide a more personalized learning experience that can optimize their understanding, motivate, and increase learner's engagement, and overall learning outcomes.

When the VARK learning styles are applied to the adaptive e-learning system, the learning style acts as an indicator for tailoring to the learner's needs from the content deliveries and instructional materials. While the four learning styles can be the main foundation of an adaptive e-learning system for catering to the needs of learners, it is important to remember that people cannot be categorized specifically. The VARK learning style is flexible enough to be modified if needed and can be used with more than one learning style. This can be called multimodal. Adding a multimodal mode by fusing the features of the four main learning styles can further enhance the adaptive e-learning system into a more effective one. This can be achieved by letting the learners choose their preferred VARK features or by incorporating interactive multimedia elements for instance virtual reality, a simulation media where any risk is low to stimulate their senses. By adding this approach, learners can further delve into immersive learning experiences and achieve their full potential. It needs to be noted that some adjustments might be needed since not all learning materials are suitable for this.

In conclusion, it needs to be kept in mind that the multimodal learning style is also a part of the VARK learning styles and is crucial for the needs of the learners. With the advancement of technology, we can look forward to a more accommodating, inclusive, and effective personalized learning system to help learners' study with their own unique needs and preferences.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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