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Research Article

Towards an Enhanced Adaptive Learning Framework: Integrating Blended Learning and Educational Technology

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ABSTRACT

The quality of education today significantly impacts student performance and academic achievements. Adaptive learning has emerged as a strategic approach to enhance educational quality by replacing conventional one-size-fits-all methods, which often fail to address diverse student needs. However, existing adaptive learning frameworks predominantly rely on e-learning platforms, despite many educators still favouring face-to-face instruction in the classroom as their primary platform. Therefore, this research article aims to propose an adaptive learning framework that integrates a blended learning environment while leveraging educational technology. This research uses literature reviews, interviews, and questionnaires to develop the proposed adaptive learning framework, the Adaptive-Decision Support System-Learning Framework (A-DSS-LF). The A-DSS-LF comprises four primary components: the learning process, learning assessment, adaptive decision support system, and adaptive profile—the validation of the proposed A-DSS-LF involves experts from the education field. Presentations and discussions were conducted to gather their feedback and reach a consensus on the framework's validity. The findings of the Fuzzy Delphi Analysis reveal that the proposed A-DSS-LF garnered a positive reception from experts. However, valuable feedback was also offered for potential enhancements to the framework. The proposed A-DSS-LF provides educators and students with alternative learning strategies within a blended learning environment, customised to meet students' individual needs. It also leverages existing technology as a supportive learning tool.

Keywords: Adaptive learning, blended learning, learning framework, student's needs, decision support system

INTRODUCTION

Education has significantly transformed in recent years due to technological advancements, leading to a shift towards more personalised learning experiences. One innovation that has gained traction is adaptive learning, which tailors' instruction to meet each learner's unique needs. Adaptive learning systems can dynamically adjust content, pace, and delivery methods using data and algorithms to optimise outcomes. The learning environment has evolved from being limited to the classroom to a more flexible setting where students can learn anywhere, utilising available facilities. As a result, blended learning has been introduced and implemented. Blended learning combines traditional face-to-face instruction with online components, offering flexibility and customisation while maintaining the benefits of in-person interaction. This approach has been increasingly adopted worldwide, allowing for a more individualised and practical learning experience.

Adaptive learning is a pedagogical approach that has gained popularity recently due to its potential to personalise education and improve student performance across various fields, including computing and non-computing disciplines [1]. It involves using technologies that dynamically adjust the level or type of course content based on an individual's abilities or skill attainment [2]. This approach can accelerate a learner's performance through both automated and instructor interventions, and it is closely related to artificial intelligence [2]. The

benefits of adaptive learning are numerous. It can provide a viable alternative to time-consuming tutor-led individual support by targeting precise areas of development, which is particularly useful in developing employability skills among higher education students [3]. In massive open online courses (MOOCs), adaptive learning has increased learning gains without significantly affecting dropout rates [4]. Smart classroom environments can further enhance the adaptive learning experience by considering factors such as motivation, prior knowledge, cognitive load, and environmental parameters [5].

In adaptive learning, a Decision Support System (DSS) plays a pivotal role in informed decision-making, enhancing the learning process significantly. The DSS's involvement is multifaceted, primarily focusing on personalised learning paths, content recommendation, progress tracking, feedback and intervention, and resource allocation. An adaptive examination system has been developed to tailor testing based on user preferences. This system incorporates a decision support feature that dynamically weights subject domains to produce a temporary ranking among test examinees, with graduation determined by set rules [6]. Adaptive assessment in e-learning environments utilises machine learning models such as decision trees and decision rules. These models adopt the testing procedure to the performance and knowledge of test participants, as well as the goals of educators [7]. A DSS has been proposed to assist educational institutions in determining the best learning method. This system takes into account various assessment criteria and alternative solutions to support decision-making tailored to the conditions of schools, teachers, and students [8]. Overall, integrating a DSS into adaptive learning enhances the educational experience, providing personalised learning opportunities, efficient resource allocation, and valuable insights for educators and administrators.

Blended learning often involves a mix of in-person classroom sessions, online self-paced activities, and other forms of digital interaction, offering a flexible and personalised learning experience. In school settings, blended learning was found to be considerably more effective than online learning, with computer-assisted instruction being the most effective form of digital technology [9]. In the context of English as a Foreign Language (EFL) learning, a blended learning model that combines content-based instruction with collaborative and autonomous learning was efficient, improving students' listening and speaking proficiencies [10]. Students in higher education expressed a preference for a blended learning environment, finding e-tutorials valuable in reinforcing classroom learning despite some technological challenges [11]. In conclusion, the synthesis of research across various educational contexts indicates that blended learning is generally more effective than traditional e-learning. It enhances knowledge outcomes and satisfaction and supports interactive and collaborative learning experiences. Integrating face-to-face and online components seems to be a key factor in the success of blended learning, providing a more engaging and effective educational approach.

As mentioned, both adaptive and blended learning environments are implemented through educational technology. Adaptive learning practices in blended learning environments integrate technology to enhance the educational experience by addressing challenges in traditional learning. The recent shift towards e-learning, accelerated by the COVID-19 crisis, has highlighted the importance of such practices for pedagogical continuity. An adaptive system for blended learning can be structured with contextual, pedagogical, and instrumental subsystems, focusing on the adaptability of educational materials, individualisation of the learning process, and personalisation of the educational environment [12]. The effectiveness of blended learning is enhanced by adaptive learning systems that utilise big data and artificial intelligence, which can positively impact learning engagement and effectiveness by promoting self-management and adaptation to blended learning environments [13]. This article explores integrating blended learning and educational technology into an enhanced adaptive learning framework. By combining the strengths of both approaches, educators can create a more engaging, personalised, and efficient learning environment. The integration of these elements has the potential to revolutionise education, providing learners with a more tailored and effective learning experience.

RESEARCH BACKGROUND

Every day, educators strive to enhance the effectiveness of teaching and learning. The challenge faced by teachers is how to handle the diverse learning needs of each student. Every student is unique and learns differently. Students are unique from various perspectives, such as their learning styles, achievements in exams or tests, ability to perform tasks, and attitudes. Studies by [14], [15], [16] have explored how students' unique characteristics influence their academic performance and engagement with different learning and assessment methods. These studies suggest

that students are exceptional in their learning preferences, motivations, self-efficacy, epistemic beliefs, and backgrounds, which affect their performance and experiences in education. [17], [18], [19] have conducted research focusing on Malaysian education. Their findings emphasise that learning styles and intelligence profiles significantly affect students' academic performance in Malaysia. These studies contribute to understanding how factors specific to the Malaysian context influence student learning outcomes.

However, despite advancements in educational practices, the one-size-fits-all pedagogy is still prevalent among educators for various reasons. This approach often proves inadequate due to the diverse characteristics of students. Not all students can effectively engage with the same material, and their optimal learning methods vary. This discrepancy can hinder students from effectively achieving learning objectives. The one-size-fits-all approach in teaching and learning is generally ineffective because it fails to accommodate individual differences in students' abilities, learning patterns, preferences, prior knowledge, pace, and the diversity of student populations [20], [21], [22], [23], [24]. To address this challenge, many researchers have turned to adaptive learning methods. Adaptive learning leverages computers as interactive teaching devices, adjusting teaching resources or educational material to meet the specific learning needs of students.

Adaptive learning systems demonstrate a high degree of compatibility with various levels of education, from primary to professional academic levels. They effectively personalise learning experiences according to individual proficiency, emotional and psychological traits, and intellectual development goals. These systems are being integrated into different educational models, including MOOCs, STEM education, and higher education, to enhance learning outcomes and support the development of individual qualities [2], [21], [25], [26]. Implementing adaptive learning in Malaysian education faces challenges due to limited technological infrastructure, traditional teaching methods, and a lack of educator training. Cultural factors and cost constraints also play a role, along with the need to adapt the curriculum and address data privacy concerns. Integrating adaptive learning with existing systems is complex. Overcoming these challenges requires investment, training, and a focus on data privacy, along with efforts to align adaptive learning with cultural and educational norms in Malaysia.

The problem statement highlights two key challenges facing the Malaysian education system related to implementing an adaptive learning system to improve student achievement in education. While previous adaptive learning implementations have heavily relied on e-learning technologies, Malaysia favours traditional classroom-based learning approaches, especially in rural areas with limited educational technology facilities. However, there is a growing recognition of the need to integrate educational technology to modernise and enhance learning and teaching practices. Secondly, the diverse range of learner needs within the Malaysian education context, encompassing learning styles, mastery levels, affective factors, and skill abilities, presents a significant challenge. Addressing these varied needs is crucial for effectively implementing adaptive learning frameworks in Malaysian educational settings. Therefore, this research aims to propose an adaptive learning framework tailored to the Malaysian education landscape, addressing these challenges to enhance student learning outcomes and experiences. This research aims to propose an adaptive learning framework tailored to the context of Malaysian education. This study focuses on two specific objectives. Firstly, it seeks to develop a comprehensive framework for adaptive learning that integrates identified constructs and elements, considering the consensus among field experts. Secondly, the research aims to validate the developed framework through expert review and feedback to ensure its suitability and effectiveness in Malaysia's prevalent blended learning environment. The proposed framework will integrate blended learning and educational technology, cater to learner needs, and incorporate a decision support system (DSS) to generate learner adaptive profiles. Ultimately, the goal is to enhance students' learning experience and academic performance, specifically addressing the challenges of limited e-learning use and dominant classroom approaches in Malaysia. The research will involve designing, developing, and validating the adaptive learning framework to assess its constructs and components in meeting the diverse needs of students and improving learning outcomes in the Malaysian context.

LITERATURE REVIEW

1.1 Adaptive Learning Framework

Adaptive learning frameworks are particularly relevant in addressing the diverse needs of learners in modern educational settings. Students today come from various backgrounds and possess different levels of prior knowledge, learning styles, and interests. Adaptive learning frameworks can adapt to these differences, offering tailored learning

experiences that meet individual needs and preferences. This adaptability is especially beneficial in environments with large class sizes, where individualised attention may be challenging for educators to provide.

[27] proposed a versatile, adaptive framework for designing Adaptive Virtual Learning Environments (AVLEs), drawing on insights from existing literature. AVLEs, in the context of e-learning, are customised to cater to students' learning styles, cognitive abilities, and performance levels, offering personalised learning strategies, content, and navigational support. According to Figure 1. the framework consists of three core modules: The Content Domain Model, which organises learning resources for adaptability; the Student Model, which includes data on student characteristics such as knowledge level, performance, learning style, and motivation; and the Adaptation Model, which uses information from the student and content domain models to deliver suitable learning resources to students. Additionally, the framework includes ancillary modules like the Interaction Data Monitor, which tracks student interactions to inform updates to the student and adaptation models, and the Interaction Module, the user interface through which students engage with the learning content. The framework is designed to be domain-agnostic (solutions focus on solving problems across multiple domains - not just one) and adaptable to various learning areas, student characteristics, or adaptive techniques, thus enhancing its versatility for diverse AVLE applications.

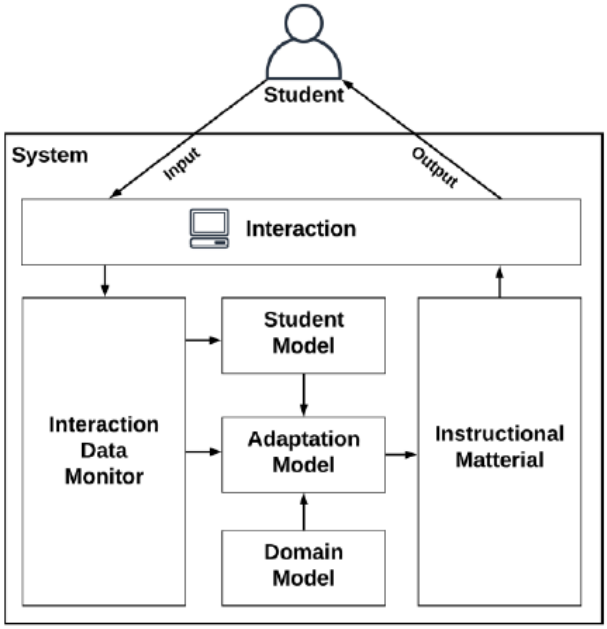

Figure 1: Adaptive Virtual Learning Environments

[28] discuss Adaptive Learning Systems (ALS), which range from simple rule-based systems to complex self-learning algorithms. These systems are particularly beneficial in online learning environments, where they provide personalised support for each student, addressing the challenges of large online courses that often lead to inequities in student attention. ALS typically consists of three core components: the student model, which collects data on student characteristics; the domain model, which encompasses the content and structure of the subject matter; and the adaptive model, which uses information from the other two models to deliver personalised learning activities and feedback. The design process for implementing ALS involves data gathering from students, modelling student profiles, identifying adaptation opportunities, and providing the adaptations.

[29] introduced the ULearning Knowledge Level (ULKL) framework, as illustrated in Figure 2, an adaptive learning approach designed to enhance learners' education by tailoring content to their individual knowledge levels, thereby reducing student dropout rates. The framework begins by assessing a learner's knowledge through a questionnaire and a primary test upon registration. Subsequently, the learner's knowledge level is calculated, and a secondary test is administered to gauge initial understanding before the system adapts to the learning material. Utilising the C4.5 algorithm, a dynamic decision tree approach, the system recommends learning objects that align with the learner's knowledge level, continuously assessing and adjusting to the student's performance throughout the course. This precise determination of a student's knowledge level is crucial for providing an effective learning

experience and facilitating the achievement of educational goals. Following the learning process, a final test evaluates the success of the adaptation process. Based on the C4.5 decision tree algorithm, the system's decision-making considers factors such as the learner's years of experience, age, previous test attempts, and primary test grades to estimate knowledge levels. The system's classification results are displayed in the knowledge level column, indicating the learner's assessed knowledge after the process.

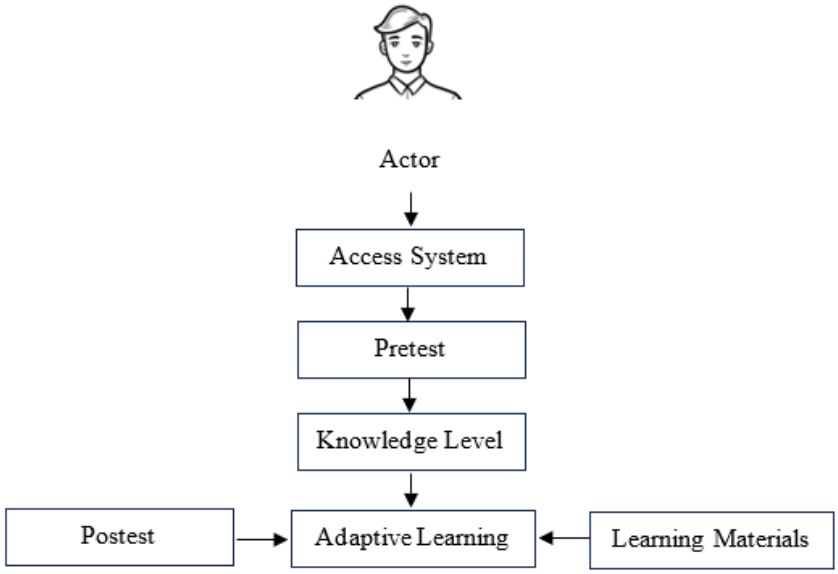

Figure 2: ULearning Knowledge Level (ULKL) Framework

METHODOLOGY

A comprehensive qualitative and quantitative study was conducted to propose an adaptive learning framework tailored to the Malaysian education landscape. This study aims to answer two primary research questions: what are the essential constructs and elements involved in designing and developing a framework for adaptive learning in the blended learning environment, and what is the level of consensus among experts regarding these constructs and elements? The framework proposal consists of two phases: framework design and framework validation. The following section discusses the research design for the proposed adaptive learning framework in detail.

Phase I involves a comprehensive feasibility analysis, which includes conducting a literature review, document analysis (Standards-Based Curriculum and Assessment Document), and interviewing experts in the field of education. This phase aims to analyse existing adaptive learning frameworks, gather insights from experts, and identify the essential elements of the framework. The literature review helps identify current frameworks, understand their design and effectiveness, and pinpoint gaps in adaptive learning environments and student needs. Expert interviews ensure that the framework addresses various needs and considers challenges such as technological constraints. This analysis evaluates the suitability of existing frameworks for Malaysia and aims to create a sustainable, effective, and adaptable framework for the education system's future changes.

Phase II utilised the Fuzzy Delphi Method (FDM) with questionnaires to validate the designed framework and improve it based on expert feedback gathered during the data collection process. Experts were carefully selected for this method. A questionnaire with open-ended questions was developed to gather insights from these experts, and their responses were meticulously analysed to identify areas of consensus and divergence. The questionnaire was refined based on this analysis, and the process was iterated until a consensus was reached. The primary aim of using the FDM was to achieve consensus among experts regarding developing an adaptive framework, focusing on its constructs and elements through iterative rounds of questionnaires and feedback.

In Phase I, in-depth interviews were conducted with 10 educators selected from the field of education. This sample size aligns with [30] recommendation suggests that a sample size ranging from 5 to 50 is adequate for qualitative research. In Phase II, 24 experts from the same field as those in Phase I were selected based on the study's criteria and in compliance with the FDM. This method involved presenting the developed framework to the experts

in parallel with a discussion, followed by their completion of a questionnaire. The number of experts used was based on recommendations from previous researchers. [31] suggested that 10 to 15 experts are sufficient if there is uniformity (homogeneity) among them. Meanwhile, [32] stated that the number of experts in FDM studies varies between six and 20 participants depending on the topic.

RESULTS

1.2 Adaptive Decision Support System Learning Framework

This study's proposed adaptive learning framework is the Adaptive-Decision Support System-Learning Framework (A-DSS-LF). Findings from Phase I highlight four main constructs in the A-DSS-LF: the learning process, learning assessment, adaptive decision support system (adaptive learning system), and adaptive profiles, with components identified for each construct.

One of the key purposes of proposing the A-DSS-LF is its potential utility across multiple levels of education in Malaysia. Therefore, the findings of Phase I suggest implementing the adaptive learning process in a blended learning environment, which combines classroom and online learning. This approach leverages existing educational technology facilities to enhance the learning experience. Previous studies have shown that blended learning is generally accepted in Malaysian education across various levels, with readiness and acceptance influenced by demographic factors, perceived benefits and challenges, and the support and resources available. Furthermore, this study emphasises two key elements in the learning process: a learning approach compatible with blended learning, characterised by self-regulated learning outside the classroom, and a student-centred approach within the classroom. The proposed A-DSS-LF does not specifically specify the type of teaching strategy to be carried out by the instructor. The choice of teaching strategy is influenced by various factors, including educational goals, student characteristics, classroom environment, and the subject matter being taught. Teachers' teaching style, time constraints, assessment requirements, available resources, professional development, and external factors such as educational policies and community expectations can impact their decisions.

Considering the learning process in blended learning and the available approaches to collecting learner data, it is recommended to use conventional methods for gathering learner needs data during learning assessments. This recommendation contrasts with the prevalent use of automated approaches in many adaptive e-learning systems. However, this choice is deemed relevant to the current situation in Malaysia's education landscape. Based on the findings from Phase I, four types of learner data will be collected during the learning assessment: learning style, level of knowledge, skill ability, and the value practised by the learner throughout the learning process. All the data will be collected using instruments prepared by instructors, except for learning style, which will be assessed using the Index of Learning Styles (ILS) developed by [33]. A-DSS-LF specifies the elements that instructors should consider when developing their instruments. The document analysis results indicate that three components should be emphasised when preparing instruments to gather the learning status of each student: identifying the learning objectives to be assessed, determining the learning domains to be evaluated, and specifying the mastery levels for the results gathered from the assessments.

After the instructor systematically collects learner needs data using specific instruments, the Adaptive Decision Support System (ADSS) processes the learning assessment data. Phase I findings reveal that A-DSS-LF includes a learner, adaptation, and learning object models, similar to existing adaptive learning systems. The DSS plays a crucial role in defining the learner model for each learner based on the system's data, rules, and criteria. It also establishes the learning style for each learner based on their preferences in the four dimensions of the FSLSM: visual/verbal (input), sensory/intuitive (perception), sequential/global (understanding), and active/reflective (processing). The adaptation model in the ADSS includes adaptation rules and strategies. Adaptation rules govern how the system adapts based on factors such as the learner model, which determines the type and presentation of content or resources. Adaptation strategies are predefined approaches or techniques the system uses to implement adaptation rules effectively. The learning object model in the ADSS encompasses the structure, content, and delivery of learning materials. It includes individual learning objects such as text, images, and videos, along with metadata for organisation. This model defines how these objects are arranged and sequenced to create meaningful learning experiences, often incorporating interactive elements. Additionally, assessment and feedback mechanisms are integrated into the model to track progress and provide guidance.

The proposed A-DSS-LF generates a personalised learner profile, or adaptive profile, comprising a learning path, feedback, and recommended learning objects. The learning path is designed to enhance proficiency in each learning domain: knowledge, skill, and value. This personalised path guides students through the learning process, highlighting areas where they need improvement and focusing on their needs. By following this tailored path, students can effectively enhance their knowledge, develop their skills, and reinforce their values, ultimately improving their learning outcomes. One critical responsibility of teachers is to offer individualised, timely feedback to each student, leveraging their unique learning assessment data. In the proposed framework, an ADSS assists teachers in delivering such feedback. The ADSS ensures that feedback is customised to each student's current performance, considering their mastery of a particular topic. This personalised feedback enhances the learning experience by tailoring guidance to each student's needs, facilitating further learning. The learning objects recommended by the A-DSS-LF are selected based on the student's learning style, catering to their specific needs and preferences, thus enhancing the effectiveness of the learning process.

1.3 Validation of A-DSS-LF

To complete Phase II, two rounds of the FDM were conducted to achieve the desired level of expert consensus for the proposed A-DSS-LF. Out of 24 selected experts, 15 could participate in the discussions to validate A-DSS-LF. After the debate, respondents were given two weeks to complete the questionnaire. The expert consensus data analysis in Phase II revealed that all respondents agreed with the constructs and elements proposed in the A-DSS-LF. Below are the main findings from the discussion session and open-ended questions in the questionnaire that should be taken into consideration to improve the proposed A-DSS-LF:

"I suggest using the term 'learner' to represent one of the models in the Adaptive DSS construct, the Learner Model, instead of the term 'Student Model.' 'Learner' is more flexible and suitable for use in the framework because the proposed framework can be used at many levels of education and is not limited to students in schools only."

"...we should make sure the learning styles shown in the framework are clear. Like in the slides, we could include the four dimensions of the Felder-Silverman model in the framework itself. That way, it's easier for everyone to understand, instead of using the abbreviation 'FSLM,' which not everyone might know."

"Researchers are recommended to investigate the DELIMA 2.0 digital learning platform (PdP resource centre) and the idMe assessment platform (comprehensive student assessment record centre). Both platforms are closely related to the researchers' study."

"Establish a support group among teachers to prepare assessment instruments and learning resources."

Based on the findings from the literature review, interviews, and expert discussions, Figure 3 depicts the proposed adaptive learning model developed and validated by the experts.

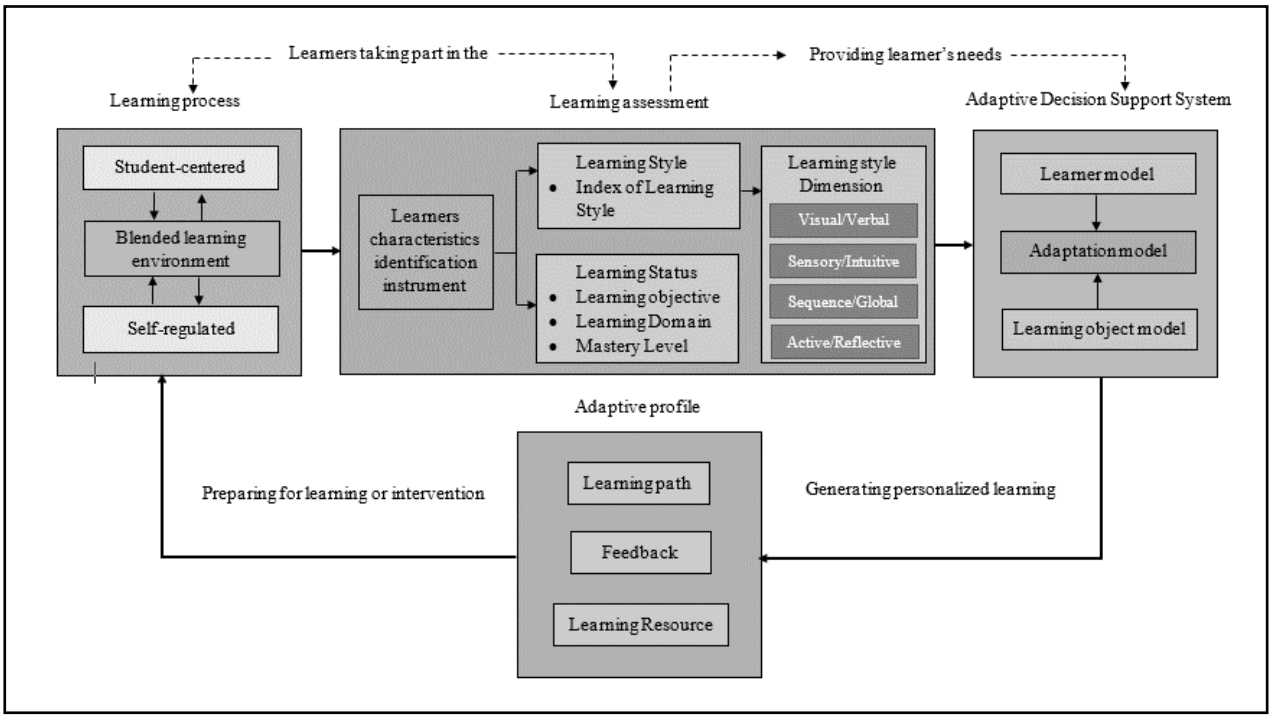

Figure 3: Adaptive-Decision Support System-Learning Framework

Figure 3 presents four key constructs: the learning process, learning assessment, ADSS, and adaptive profile, along with their identified elements. Implementing teaching and learning using A-DSS-LF is not limited to a single cycle; it can be utilised until students achieve their learning objectives. Two implementation strategies for teaching and learning can be employed with A-DSS-LF. The teacher determines these strategies based on whether they are preparing for learning or intervention. Figure 4 shows the strategy of implementing A-DSS-LF for teaching and learning.

Based on Figure 4, the A-DSS-LF framework's sequence between learning and learning assessment can vary depending on the teacher's approach. If a teacher chooses to prepare for learning, A-DSS-LF recommends starting with an assessment before moving on to the learning process. For example, if a teacher decides to prepare the teaching and learning materials for a new topic, they may assess their students' existing knowledge and skills first. This assessment helps the teacher understand their students' current level of knowledge and skills, enabling them to tailor their teaching approach accordingly. This approach allows teachers to gather valuable data on student performance from the adaptive profile, which can be used to tailor the learning process to meet students' needs.

On the other hand, if a teacher chooses to prepare for intervention, the sequence may be reversed compared to preparing for learning. In this case, the teacher would typically start with the learning process before conducting a learning assessment. This sequence allows students to engage with the material first, followed by an assessment to evaluate their understanding and identify specific learning needs requiring intervention. The teacher can then plan and implement targeted interventions based on the assessment results. Subsequent assessments can be conducted to measure the effectiveness of the interventions and make further adjustments as needed.

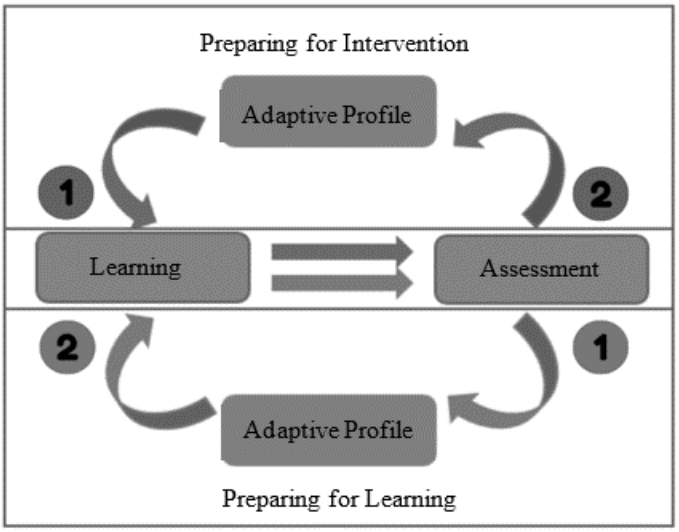

Figure 4: Strategy of Implementing A-DSS-LF

DISCUSSION

A-DSS-LF recommends that adaptive learning be implemented in the blended learning environment. This method offers a more flexible and personalised learning experience, which can lead to improved student outcomes. Previous research shows that blended learning provides numerous benefits across educational levels and contexts. [34], [35], [36], [37], [38], [39], [40], [41], [42]. Higher education enhances access to learning materials and supports individualised learning paths. In elementary schools, it aids reading instruction and benefits students with lower reading performance. Using digital platforms and online tools enhances learning experiences at all levels, particularly during emergencies like the COVID-19 pandemic. Careful planning, infrastructure consideration, and educator training are crucial for successful implementation. Blended learning can also reduce disparities and increase motivation, especially when started early and supported by clear communication and ongoing assessment. Despite challenges related to technology and professional development, blended learning remains a valuable strategy for improving educational outcomes and maintaining continuity during disruptions.

The proposed A-DSS-LF emphasises self-regulated learning (SRL) and student-centred learning (SCL) as pivotal for enhancing effectiveness. Research consistently underscores the efficacy of SRL in blended learning environments, correlating with improved academic performance and learning skills when SRL strategies are appropriately supported and scaffolded. Notable studies support these findings. For example, an experimental study revealed a significant difference in SRL between students in blended and offline classes, with the blended approach fostering superior SRL [43]. Additionally, in a study by [44] on flipped blended learning for music teacher education, using learning analytics uncovered significant relationships between specific SRL behaviours and academic achievement, showcasing the potential of analytics in supporting SRL. Similarly, research in English learning environments by [45] demonstrated a positive link between SRL and learning outcomes, with no significant gender differences in SRL strategy use. Moreover, implementing a framework for designing peer learning self-regulation strategy systems in blended courses resulted in significantly higher academic scores and learning outcomes [46]. Collectively, these studies provide robust evidence supporting SRL's critical role and effectiveness in blended learning environments.

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[46] implemented a framework for designing peer learning self-regulation strategy systems in blended courses, resulting in significantly higher academic scores and learning outcomes. These studies provide robust evidence supporting SRL's critical role and effectiveness in blended learning environments.

Extensive research has supported the promotion of SCL in A-DSS-LF. In higher education, practices like flipped classrooms, a form of SCL, support personalisation, higher-order thinking, self-direction, and collaboration, leading to positive student outcomes [47]. Reforms in blended teaching that emphasise learning-centred approaches can transform passive learning scenarios into active participation, fostering innovative and critical thinking skills [48]. Implementing SCL through lesson study improves the quality and effectiveness of student learning outcomes while enhancing leadership skills [49]. Cooperative learning practices, integral to SCL, enhance learning efficacy, student engagement, comprehension, knowledge application, and social skills in university classrooms [50]. Design thinking, a user-centred approach, promotes SCL by creating authentic learning experiences centred around student needs [51]. Student-centred learning environments, through interactive activities and self-paced learning, encourage independent problem-solving and foster lifelong learning [52].

As illustrated in Figure 3, learning assessment involves dynamically and comprehensively identifying students' learning needs (characteristics). This process includes assessing their learning styles and learning status across three domains: cognitive, skills, and values. The proposed A-DSS-LF specifically recommends addressing four students' learning needs to enable the ADSS to make decisions regarding providing an adaptive profile for each student. These recommendations are grounded in the perspective of education in Malaysia. This research highlights various student learning needs, a concept supported by previous research. They also conclude that these considerations underscore the importance of developing adaptive learning systems. Such systems should be responsive to the diverse characteristics and preferences of students while also addressing the challenges of implementation and effectiveness in different educational contexts [26], [53], [54], [55], [56], [57].

CONCLUSION

The proposed A-DSS-LF is an example of a support tool for instructors seeking to enhance the effectiveness of the learning process, ensuring that student's needs are addressed individually. It allows teachers to treat each student uniquely based on their adaptive profile. Every day, teachers must decide how best to ensure that each student effectively reaches their maximum learning potential. The ADSS construct in the proposed A-DSS-LF aids teachers in making better decisions. An ADSS offers a unique advantage in education by providing tailored recommendations and real-time insights that are difficult to achieve through conventional methods. ADSS leverages individual student data, including learning styles, preferences, and performance, to provide personalised guidance. This level of personalisation is a key strength of ADSS, as it allows educators to cater to the specific needs of each student, which can be challenging with traditional approaches.

Moreover, ADSS provides immediate feedback on student progress and performance, enabling teachers to adjust their teaching strategies promptly. In contrast, conventional methods often rely on periodic assessments and observations, which may not capture real-time learning needs. This real-time insight is crucial for educators to effectively address student challenges and optimise their learning experiences. Additionally, ADSS can be scaled to support many students, ensuring each learner receives personalised recommendations and insights. This scalability is a significant advantage over conventional approaches, which may struggle to provide such individualised support on a large scale. In summary, ADSS's ability to offer personalised recommendations, real-time insights, and scalable support makes it a valuable tool for enhancing educational decision-making, ultimately leading to improved student learning outcomes.

Based on findings from interviews with research respondents, this study revealed that many teachers do not have well-prepared instruments for assessing students' ability to practice certain skills, such as computer skills, in basic computer science courses. Similarly, there is a lack of well-prepared instruments in the affective domain to assess the values practised by students throughout the learning process. Unlike the cognitive domain, which is the main focus in education for assessing student achievement and where it is easier to gather data on students' level of knowledge, the practical skills and values preservation domains are often overlooked. Respondents suggested that the research propose examples of well-prepared instruments to assess practical skills and values preservation among students to complete the learning assessment data for all three domains. Instruments based on the proposed elements to evaluate

students' status of learning practical skills and values will be developed for this study to achieve the objectives of this research.

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