An Effective One-Hour Differentiated Instruction Model for Enhancing Student Engagement and Learning Outcome

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***Abstract*— This paper presents a framework for teaching a one-hour computer networks class using adaptive learning. The goal is to meet the different learning needs of students by offering personalized instruction and varied content. The class covers basic network topologies and models, using an adaptive platform to personalize instruction based on student understanding. Through interactive lectures, group activities, and adaptive quizzes, students receive a customized learning experience that helps them grasp the fundamentals of computer networks effectively. Results showed that students who received personalized instruction were more engaged and performed better on assessments. The discussion emphasizes the benefits of differentiated instruction and adaptive learning technologies in improving learning outcomes, despite initial setup challenges. In conclusion, this framework effectively enhances student understanding of computer networks by providing customized and interactive learning experiences.**

***Keywords*— Adaptive learning, student engagement, educational technology, personalized learning, classroom effectiveness, instructional design.**

ICTIEE* Track*: Pedagogy of Teaching and Learning
ICTIEE Sub-Track: Differentiated Instruction in Meeting the Needs of Every Student

I. Introduction

Computer networks form the backbone of modern communication and technology, and mastering their fundamentals is crucial for students pursuing careers in computer science and related fields. Traditional teaching methods, however, often fail to address the diverse learning needs of students. Many students enter computer networks courses with varying levels of prior knowledge, learning preferences, and paces. This diversity can make it challenging to provide a one-size-fits-all instruction that effectively engages and educates every student. Adaptive learning offers a solution by personalizing the educational experience to meet individual needs, thereby improving both engagement and comprehension. The motivation behind adopting an adaptive learning framework in a computer networks course stems from the desire to enhance student outcomes and satisfaction. Traditional methods of instruction can result in some students feeling left behind or disengaged, while others may not be sufficiently challenged. An adaptive learning approach aims to bridge this gap by offering personalized learning paths, interactive content, and real-time feedback. This method not only helps in addressing individual learning differences but also fosters a more inclusive and effective learning environment. By tailoring instruction to each student's needs, adaptive learning can lead to better understanding of complex topics and improved performance on assessments.

II. Literature Review

The paper discusses the concept of differentiated instruction and assessment, which involves providing various avenues for learning to students within the same classroom based on their individual needs. It emphasizes the importance of considering students' diverse learning needs, such as culture, socioeconomic status, language, gender, motivation, ability/disability, and personal interests, when planning curriculum and instruction [1]. The research paper highlights the significance of developing personalized instruction to ensure effective learning for all students in the classroom, regardless of differences in ability or background.

Various adaptive instruction tools and platforms available, such as intelligent tutoring systems, learning management systems, mobile apps, AI chatbots, and adaptive machine-learning programs, emphasizing the diverse options for implementing adaptive learning are discussed in [2]. The authors also introduce the Adaptive Instruction of Student Control Theoretical Framework, which suggests that allowing students to control their use of learning resources can lead to improved learning outcomes, emphasizing the significance of student autonomy in the learning process.

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The skills and knowledge are required by teachers to provide differentiated instruction using adaptive learning systems (ALSs) with teacher dashboards, compared to traditional methods. The teacher dashboards can assist in providing up-to-date information about students' progress, utilizing this new information effectively demands additional skills such as interpreting dashboard data and understanding the calculations in the ALS [3].

Teachers often face challenges in assessing student performance and providing timely feedback due to constraints like time, resources, and skills. Lack of proper diagnosis and support can lead to students being unable to engage effectively in grade-level instruction. Digital personalized and adaptive learning (PAL) approaches are highlighted in [4] as solutions to deliver tailored instruction quickly at scale.

There is a lack of methods on how to measure successful adaptation and its effects due to varying theoretical and methodological assumptions. Three main types of studies are outlined in [5]: Studies focusing on overall effects of adaptive teaching. Studies with an adaptive teaching intervention perspective. Studies examining the variability of student performance. These studies help in understanding how adaptive teaching practices impact student learning outcomes and educational effectiveness.

Intelligent tutoring systems (ITS) are utilized in [6] to deliver adaptive instruction, tailoring learning experiences to meet the needs and preferences of individual learners or teams. Adaptive instructional systems (AISs) leverage human variability and learner/team attributes to develop or select appropriate strategies and actions, aiming to optimize learning outcomes, performance, retention, and skill transfer between training and operational environments.

Adaptive learning enhances student engagement by tailoring educational experiences to individual needs, thereby increasing participation and motivation. Research shows that adaptive e-learning leads to a significant rise in online discussion participation, assignment submissions, and Learning Management System (LMS) usage, with a regression analysis confirming a strong link between adaptive e-learning utilization and increased engagement [7]. Additionally, the application of adaptive gamification in digital learning environments, such as personalized gamified experiences and productive online collaboration frameworks, has been proven to promote motivation and engagement among students, overcoming the limitations of remote learning [8][9]. Moreover, introducing adaptive and gamified digital learning lessons to lower primary school students has shown promising results in improving student engagement through personalized gamification elements like points, rewards, and different game modes [10]. Furthermore, adapting learning delivery based on students' learning styles has been found to significantly enhance engagement and learning outcomes, with matched lesson/learner pairs showing improved scores [11].

The authors in [12] used a mixed methods approach, utilizing development methods for designing the adaptive e-learning environment and a quasi-experimental research design for conducting the experiment. A learning system with adaptive-feedback emotional computing technology is introduced in [13] which shows the importance of considering various factors like emotions, attitudes, engagement, cognition, neuroscientific, and cultural psychology to enhance the quality of learning is studied.

III. RESEARCH METHOD

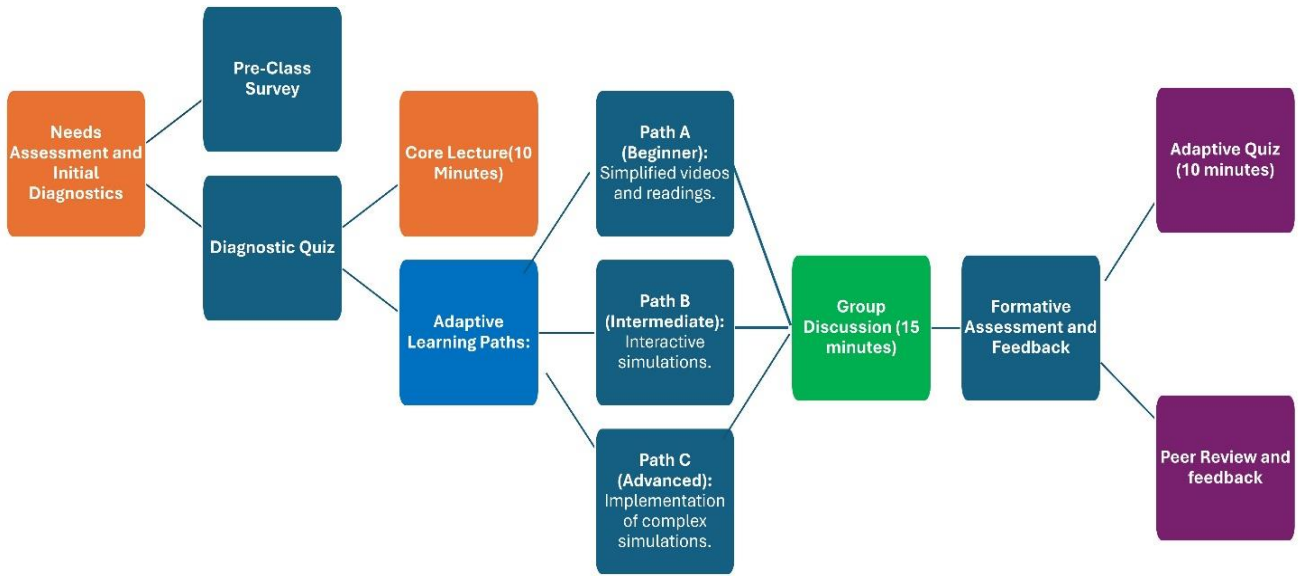

Fig. 1 Comprehensive model of one hour class

By leveraging the LearningApps service, educators can create a more engaging and personalized learning environment that fosters students' motivation and professional growth.

The study in [14] showcases how integrating interactive exercises through the LearningApps service can positively impact the educational process by tailoring it to students' specific needs and abilities. An adaptive learning system based on active learning projects for student learning in general education information technology courses is implemented in [15] which has shown students learn better due to hands-on activities and real-life applications. A model proposed in [16] utilizes AI for tailoring activities to individual learning styles, boosts engagement, minimizes disorientation, and maintains motivation throughout the learning process.

Figure 1 illustrates a comprehensive model for differentiated instruction aimed at meeting the needs of every student. Here's a detailed explanation of each component:

A. Pre-Class Survey:

This step involves collecting initial data on students' existing knowledge, learning preferences, and any special requirements they might have. This can be done through surveys where students can self-assess their understanding of upcoming topics.

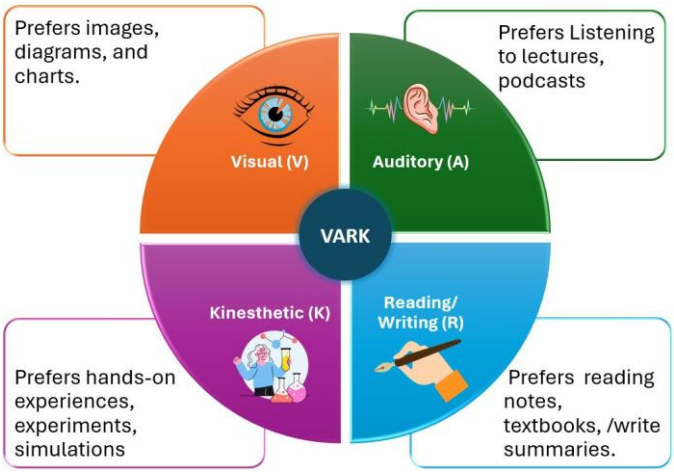

Fig. 2 VARK learning Styles

The VARK model shown in figure 2 helps teachers understand that students have different learning preferences and that teaching strategies should be adapted to accommodate these differences. By incorporating visual aids, auditory materials, reading/writing activities, and hands-on experiences, educators can create a more inclusive and effective learning environment that caters to the diverse needs of all students.

A short quiz is used to assess students' current level of understanding and skills. This helps in identifying gaps in knowledge and areas that need more focus. After this, a brief lecture (10 Minutes) is delivered to the students to introduce the core concepts of the lesson. This lecture serves as a common foundation for all students, ensuring that everyone has a basic understanding of the topic before moving on to more personalized learning paths

B. Adaptive Learning Paths and its implementation:

Based on the results of the needs assessment and diagnostic quiz, students can be directed to one of three adaptive learning paths:

- **Path A (Beginner):** Simplified videos and readings are provided for students who need more basic instruction. This path ensures that foundational concepts are thoroughly understood before moving on.
- **Path B (Intermediate):** Interactive simulations are offered to students who have a moderate understanding of the topic. This path focuses on applying knowledge through engaging and interactive activities.
- **Path C (Advanced):** Advanced simulations and complex problem-solving tasks are provided for students who demonstrate a higher level of understanding. This path challenges students to deepen their knowledge and skills.

Here are some specific topics given to students in each path:

- *Path A (Beginner):*
  - **Introduction to TCP/IP Protocols:** Simplified videos explaining the basic structure and function of the TCP/IP suite.
  - **Understanding the Application Layer:** Focused on how protocols like HTTP and FTP work in simple client-server interactions.
  - **Basic Network Topologies:** Explanation of star, ring, and bus topologies using visuals and basic examples.
- *Path B (Intermediate):*
  - **IP Addressing and Subnetting:** Interactive exercises on calculating subnets and understanding IP classes.
  - **Troubleshooting Connectivity Issues:** Simulation of network issues like IP conflicts and their resolutions.
  - **Layered Communication in the OSI Model:** Tasks exploring the interaction between the Transport and Network layers.
- *Path C (Advanced):*
  - **Routing Protocols:** Problem-solving tasks on configuring and optimizing OSPF and BGP routing protocols.
  - **Network Security Measures:** Case studies on implementing firewalls and detecting intrusions.
  - **Comparing TCP and UDP:** Analysis of performance trade-offs in real-time applications like VoIP and video streaming.

These topics were tailored to the students' levels of understanding, ensuring that each group received appropriately challenging and engaging material.

C. Group Discussion (15 Minutes):

After completing their learning paths, students from all levels—beginner, intermediate, and advanced—were brought together in mixed groups to foster peer learning and collaboration. This setup allowed everyone to share their key takeaways and learn from each other's experiences. The discussions were lively, with students asking questions, clearing doubts, and tackling topics like network troubleshooting, protocol comparisons, and

real-world applications. The instructor played an active role, making sure everyone had a chance to participate and gently steering the conversation to keep it focused on the learning goals. It was a great opportunity for students to exchange ideas, build on their understanding, and solve problems together.

D. Peer Review and Feedback(10 Minutes):

After the group discussions, students took part in a peer review session designed to help them learn from each other. Guided by simple rubrics provided by the instructor, they evaluated their classmates' work, focusing on how clear, accurate, and well-understood the solutions were. Tasks included looking at subnetting answers, reviewing how protocols were implemented, and offering suggestions on security setups. The feedback was positive and constructive, pointing out strengths and offering helpful suggestions for improvement. This activity not only boosted their understanding of the subject but also sharpened their critical thinking and communication skills. Both peer and instructor feedback were shared immediately, making the learning experience even more impactful. The table 1 shows the peer review questions given to students.

TABLE I
PEER REVIEW QUESTIONS

Clarity of Work: Is the work easy to understand?				
5: Very clear	4: Mostly clear	3: Somewhat clear	2: Hard to understand	1: Confusing
Correctness: Is the work correct and accurate?				
5: Fully correct	4: Mostly correct	3: Partly correct	2: Many mistakes	1: Incorrect
Understanding: Does the work show good understanding of the topic?				
5: Excellent understanding	4: Good understanding	3: Basic understanding	2: Limited understanding	1: Poor understanding
Creativity: Is the work creative and practical?				
5: Very creative and useful	4: Creative and somewhat useful	3: Some creativity	2: Little creativity	1: No creativity
Feedback Quality: Is the feedback helpful?				
5: Very helpful	4: Helpful	3: Somewhat helpful	2: Not very helpful	1: Not helpful at all

A second quiz is also administered to assess students' learning after the instruction and adaptive learning activities. This quiz is tailored to each student's learning path, ensuring that the assessment is relevant to the content they have studied. After this, Students engage in peer review, where they evaluate each other's work and provide feedback. This encourages critical thinking, self-reflection, and constructive criticism, further enhancing the learning experience.

IV. RESULTS AND DISCUSSION

The proposed model is implemented in one hour class of computer network course for teaching TCP/IP protocol site. In the beginning of the class, The VARK questionnaire is used to find out how students prefer to learn by identifying their learning styles: Visual, Auditory, Reading/Writing, or Kinesthetic. In this study, we gave the VARK questionnaire to a group of students and analyzed their answers to see which learning styles were most common. We found that some students had strong preferences for one style, while others liked a mix of styles as shown in figure 3. Using this information, we adjusted our teaching methods to match their learning preferences.

The assessment of the adaptive instruction method reveals significant improvements in several areas. The pre-class survey in figure 4 indicated a relatively low average confidence level of 2.8 out of 5 among students regarding their understanding of the subject matter. However, after completing the topic, this average confidence level increased substantially to 4.2 out of 5, demonstrating the effectiveness of the adaptive learning paths and tailored instructional methods. The engagement levels also showed significant improvement, with average engagement ratings rising from 2.5 out of 5 pre-class to 4.0 out of 5 post-class. This indicates that the differentiated instruction approach, which catered to various learning styles (as shown in the learning style distribution pie chart), was effective in maintaining student interest and involvement throughout the course.

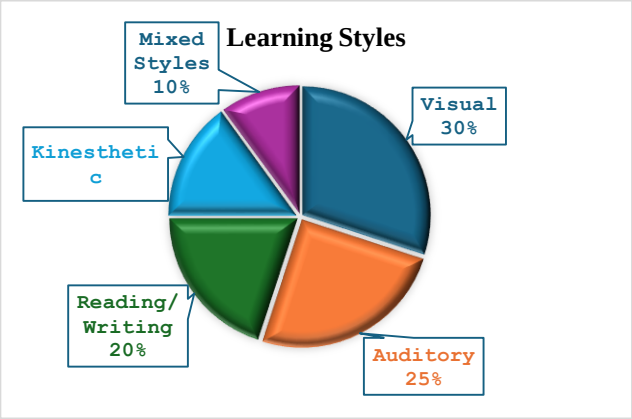

Fig. 3 Learning Styles of students

Overall, the results of this assessment highlight the success of the differentiated instruction method in meeting the diverse needs of students. The approach not only improved students' confidence and engagement but also facilitated a more inclusive and effective learning environment. Future research could focus on refining these methods and exploring additional adaptive learning technologies to further enhance educational outcomes. Participation in class discussions saw a notable rise from 20% of students often or always participating before the class to 60% post-class. This increase suggests that the interactive and varied instructional methods, including group discussions and peer reviews, successfully engaged students and encouraged more active participation.

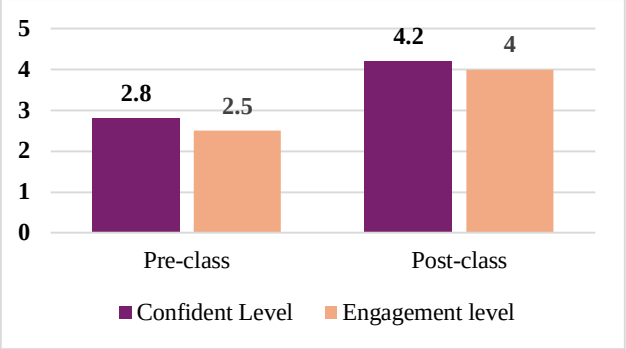

Fig.4 Student confidence and engagement

A. *Pre- and post-class quiz*

A set of 10 questions were asked to students through Socrative software tool at the beginning and end of the class to understand the student's knowledge about the topic after group discussion. Different level questions (understand, Apply, Analyze) were included in the questionnaire as shown in table 3 to examine the understanding of the topic from different learning paths.Figure 5 shows the scores of 60 students before and after a quiz, revealing that most students improved. The number of students in the highest score range (7-10) increased dramatically from 2 to 38. This suggests a substantial improvement in understanding and performance. The number of students in the lowest score range (0-3) decreased significantly from 50 to 7, indicating that most students have moved out of the struggling category. There was an increase in the number of students in the mid-range scores (4-6), from 8 to 15.

TABLE II
PRE- AND POST-CLASS SURVEY QUESTIONS

Pre-Class Survey
• On a scale of 1 to 5, how confident are you in your understanding of the course material before starting the class?
• How comfortable do you feel with your preferred learning style (Visual, Auditory, Reading/Writing, Kinesthetic) being met in the traditional instructional methods?
• How prepared do you feel to tackle the challenges presented by this course?
• How would you rate your previous experience and confidence level with similar courses or topics?
• How confident are you in understanding the feedback and assessments you will receive during the course?
Post-Class Survey
• On a scale of 1 to 5, how confident are you in your understanding of the course material after completing the class?
• How effective was the class in accommodating your preferred learning style (Visual, Auditory, Reading/Writing, Kinesthetic)?
• After completing the class, how prepared do you feel to tackle the challenges related to the course material?
• How satisfied are you with the different instruction methods used in the class?
• How confident are you in applying the knowledge and skills you have gained from this topic to future class?

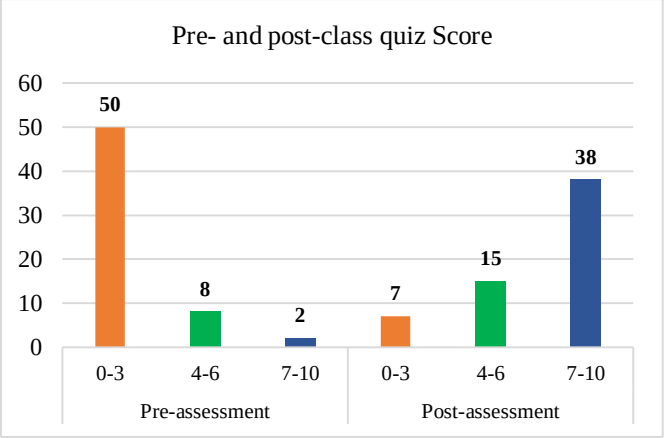

Fig. 5 Pre-and Post-class quiz Score

This may indicate that while some students improved, they have not yet reached the highest performance bracket. The data shows a positive shift in performance with fewer students scoring in the lowest range and more students scoring in the higher ranges.

The results from the group discussions and peer reviews were highly positive, reflecting the effectiveness of these activities in enhancing student learning. Students' work was rated highly for clarity, with an average score of 4.5 out of 5, indicating that most submissions were easy to understand. Correctness of solutions scored an average of 4.6, showing that students provided mostly accurate answers with minimal errors. Understanding of the topics averaged 4.4, demonstrating a solid grasp of concepts and their applications. Creativity was also evident, with students achieving an average score of 4.3 by presenting unique and practical solutions. Peer feedback was constructive and helpful, with an average score of 4.5, enabling students to improve their work effectively. These results highlight the success of the group discussions and peer reviews in fostering collaboration, critical thinking, and deeper engagement with the learning material, ultimately leading to enhanced learning outcomes.

By providing content that is appropriately challenging, adaptive learning can keep students engaged and motivated, which is crucial for improving learning outcomes. The reduction in the number of students in the lowest score bracket can be attributed to increased engagement and motivation. Immediate feedback and the ability to see their progress can boost students' confidence, making them more likely to put in the effort needed to improve. Teachers and instructors can focus their attention on students who need the most help, as the adaptive system highlights those who are struggling. This ensures that no student is left behind, contributing to the overall improvement observed in the post-assessment scores.

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TABLE III
QUIZ QUESTIONS

Questionnaire
1. What does TCP/IP stand for?
2. Which layer of the TCP/IP model is responsible for routing packets between devices?
3. Which protocol is used for reliable, connection-oriented data transfer in the TCP/IP suite?
4. In the context of TCP/IP, what is the primary purpose of the DNS (Domain Name System)?
5. Which of the following protocols operates at the Application Layer of the TCP/IP model?
6. What is the function of the ARP (Address Resolution Protocol) in the TCP/IP suite?
7. What is the purpose of the ICMP (Internet Control Message Protocol) in the TCP/IP suite?
8. Analyze the potential consequences of a network operating solely on UDP instead of TCP for a file transfer application.
9. Discuss how NAT (Network Address Translation) can affect the performance and security of a network.
10. Compare the performance and reliability trade-offs between TCP and UDP for real-time communication applications such as video conferencing.

CONCLUSION

In this paper, an effective model for designing one hour class is discussed. The significant improvement in post-assessment scores across all ranges indicates that adaptive learning methods were effective in addressing the diverse learning needs of students. The data suggests that adaptive learning facilitated a more personalized, responsive, and engaging educational experience, leading to better overall performance. As students received the right level of challenge and support, they were able to improve their understanding and skills, resulting in the observed positive shifts in assessment outcomes. Further this method can be used to investigate how the framework can be adapted for longer classes or different educational levels and subjects.

REFERENCES

Blaz, D. (2016). Differentiated Instruction: A Guide for World Language Teachers (2nd ed.). Routledge. https://doi.org/10.4324/9781315695648

Ginting, D., Sabudu, D., Barella, A. M., Woods, R., & Kemala, M. (2024). Student-centered learning in the digital age: in-class adaptive instruction and best practices. *Int J Eval & Res Educ*, *13*(3), 2006-2019.

Keuning, T., & van Geel, M. (2021). Differentiated teaching with adaptive learning systems and teacher dashboards: the teacher still matters most. *IEEE transactions on learning technologies*, *14*(2), 201-210.

Alrawashdeh, G. S. (2022) Approaches to Technology-enabled Personalized and Adaptive Learning: A Brief Overview.

Hardy, I., Decristan, J., & Klieme, E. (2019). Adaptive teaching in research on learning and instruction. *Journal for educational research online*, *11*(2), 169-191.

Robert, A., Sottilare. (2018). Applying Adaptive Instruction to Enhance Learning in Non-adaptive Virtual Training Environments. 155-162. doi: 10.1007/978-3-319-96077-7_16

L., Lalli., Thirunirai, Senthil. (2024). COVID-19 Adaptive E-Learning: Data-Driven Student Engagement Analysis. doi: 10.1109/icicacs60521.2024.10498868

Ruiting, Peng. (2024). Adaptive Gamification: Application in Online Learning and Collaboration. doi: 10.32920/26052622.v1

Borotić, G., & Jagušt, T. (2022, October). Enhancing student engagement with personalized gamification and adaptive learning strategies. In *2022 IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). IEEE.

Pinera, J. M. (2021). Adaptive Delivery as a Means to Increase Student Engagement and Learning Outcomes.

ZHANG, C., SHI, Q., & TONG, M. (2023). A Study of Multimodal Intelligent Adaptive Learning System and Its Pattern of Promoting Learners' Online Learning Engagement. *Psychology*, *13*(5), 202-206.

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, *18*(1), 53.

Liu, H. L., Wang, T. H., Lin, H. C. K., Lai, C. F., & Huang, Y. M. (2022). The influence of affective feedback adaptive learning system on learning engagement and self-directed learning. *Frontiers in Psychology*, *13*, 858411.

Varina, H. B., Osadchyi, V. V., & Shevchenko, S. V. (2023, March). Enhancing adaptive learning: leveraging interactive exercises through the LearningApps service. In *CTE Workshop Proceedings* (Vol. 10, pp. 281-293).