BOOSTING PERFORMANCE WITH AI-POWERED ADAPTIVE LEARNING

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ABSTRACT

The diversity of today's learners, with varying backgrounds and preferences, calls for a personalised approach to education. Traditional teaching methods disregard individual learning styles, pace, and strengths. This can cause some learners to fall behind or lose interest. Thus, adaptive learning through personalised and inclusive teaching strategies are essential for effective learning. Adaptive learning is a relatively new field, but it has the potential to revolutionise education by helping learners achieve their full potential. This paper explores the use of Artificial Intelligence (AI) - powered adaptive learning in engineering mathematics education. AI-powered adaptive learning uses machine learning to analyse learner data to create personalised learning roadmaps with customised content, targeted focus on specific areas and frequent practice for each learner. This approach empowers learners to receive immediate feedback and focus on their specific needs, leading to improved learning outcomes. At the end of this paper, the recommendations on how to improve AI accuracy for delivering materials and assessments will be discussed.

KEYWORDS

adaptive learning, personalised learning, self-learning, sustainable engineering education, digital transformation in engineering education, CDIO standards 7, 11

INTRODUCTION

A review of the literature shows that traditional classroom learning is not always ideal, as learners have different learning pace and needs (Kaminskiene & DeUrraza, 2020). At the School of Engineering, Nanyang Polytechnic, we have a diverse student population with a wide range of educational backgrounds: secondary, pre-university, vocational and technical education graduates, and adult learners from the industry. Teaching at the right pace for all learners is challenging, especially with average class size of twenty-two learners, it can be difficult to give individual attention to each learner (Ministry of Education, 2020). Additionally, structured curricula and lesson times limit learners' ability to reflect, internalise, and apply their learning (Kapp, 2016).

There is a growing demand for innovative and effective approaches to address diversity in the classroom and improve learning outcomes. Adaptive learning is one such approach. It utilises technology to monitor learner's progress and use data to modify teaching content based on individual needs (Becker et al., 2018).

To achieve this, real-time assessment, data analysis, and machine learning are used to continuously adjust the learning path based on learner feedback (Baker, 2012). Artificial Intelligence (AI) -driven assessments provide valuable feedback on learner performance and progress (Chassignol et al., 2018). Based on the 'report card', adaptive learning tools generate personalised study paths for each learner, recommending the most relevant materials to bridge gaps in knowledge and focus on areas for improvement.

Brightspace LeaP is an adaptive learning technology that allows instructors to create knowledge maps and adaptive pathways for each learner (Schaffhauser, 2014). This is made possible by AI analytics that monitor learner progress and automatically adjust the learning path accordingly. This personalised approach can help learners achieve better outcomes and improve their overall learning experience. However, this technology is relatively new and more research is needed to fully understand the impact of adaptive learning in polytechnic education.

APPROACH AND IMPLEMENTATION

In April 2022, Nanyang Polytechnic adopted Brightspace, a learning management system (LMS) that comes with intelligent agents that allow instructors to provide personalised learning paths for learners. The Brightspace adaptive learning system considers learning materials, learning objectives, learner data, and instructor input to create personalised learning paths for each learner as illustrated in Figure 1. The system also includes practice questions, recommended reading, and feedback mechanisms to help learners progress.

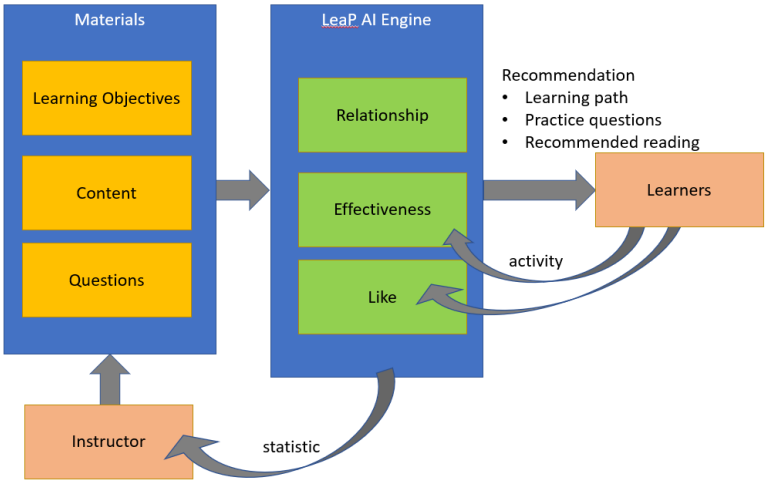

Figure 1. Adaptive Learning AI

The approach to develop the adaptive learning using Brightspace is as follows:

1. The instructor is to define the learning objectives to track the knowledge that learners acquire in the learning, as shown in Table 1.

Table 1. Define Learning Objectives

TID	Parent ID	Title	Description	Leaf?
1	0	Calculus	Calculus	
2	1	Multi-variable Functions	Differentiate multi-variable functions	
3	2	Partial Derivatives	Partial Derivatives	y
4	2	Chain Rule	Chain Rule	y
5	1	Integration by Parts	Integration by Parts	
6	5	Formula	Integration by Parts Formula	y
7	5	DI	DI method	y
8	5	DD	DD method	y

2. Using Brightspace's AI suite, the adaptive learning engine semantically maps the content materials and questions in the question bank to learning objectives, as shown in Figure 2.

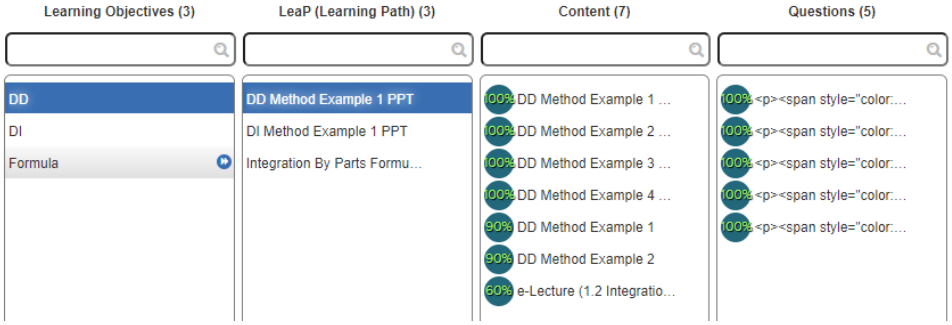

Figure 2. Automatic mapping of content and questions to learning objectives using AI

3. Learners start the adaptive learning program by taking a diagnostic test, as illustrated in Figure 3. The AI then filters out content related to learning objectives that the learner has already mastered, so that the learner can focus on their specific knowledge gaps.

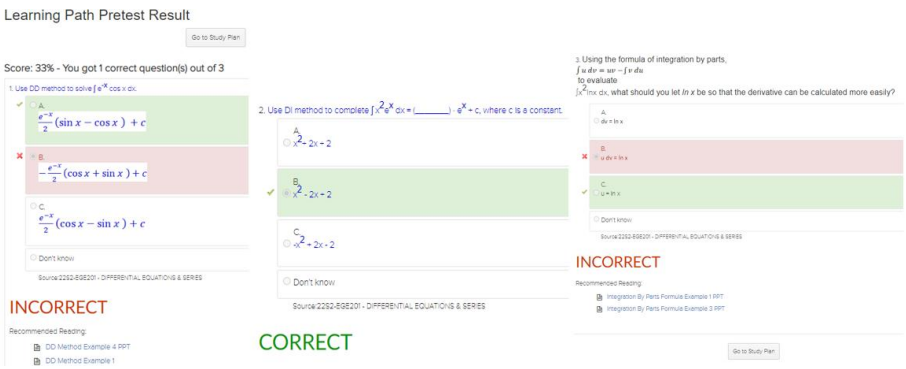

Figure 3. Diagnostic Test

4. The adaptive engine generates personalised learning plan (learning path) for each learner based on the success rate of learners answering the test questions. Figure 4 shows an example of the generated learning path which recommends study materials based on relevance to the learning objectives, effectiveness in helping the learner answer questions correctly, and the number of "likes" awarded by other learners.

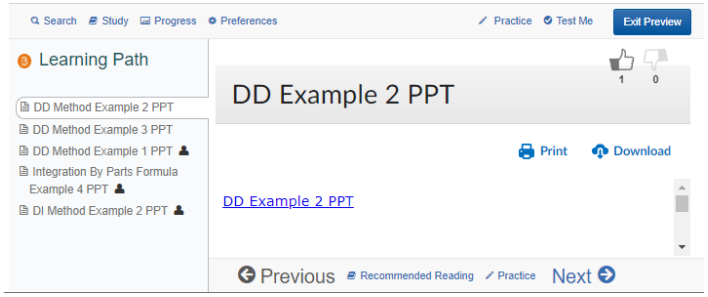

Figure 4. Personalised Learning Plan

5. Learners can access additional recommended readings and practice questions, as shown in Figure 5, to deepen their understanding. The adaptive learning engine guides them towards mastery of the material through a cyclical process of "learning, testing and reinforcement".

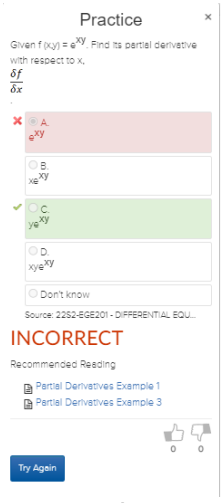

Figure 5. Practice Questions

RESEARCH AIM

The aims of this project are:
1. To use AI technology tool to customise and personalise targeted learning plan for learners.
2. For learners to assess their learning gaps and focus their energies on those areas that need help.

RESEARCH QUESTIONS

The research questions are as follows:
1. How much does the use of adaptive learning technology improve learners' performance in differential equation topics?
2. What are the perceptions of learners about the usefulness, satisfaction, and ease of use of the adaptive learning tool?

PARTICIPANTS

This study involved 86 second-year learners, aged 18 to 25, from the Diploma in Electronic & Computer Engineering (DECE). The average class size was 22, with 7% of the participants repeating the module and 6% having special learning needs. The learners' GPA ranged from 0.74 to 3.91, representing a diverse range of academic abilities.

METHODOLOGY

This study used a pre-post test within group design to evaluate the impact of an adaptive learning tool on learners' performance in two engineering mathematics topics in a mathematic module, Differential Equations and Series.

The control group consists of learners who attended the lectures and tutorials but did not use the adaptive learning tool. They attended lectures and tutorials, followed by a pre-test on the topic covered. They used lecture notes and tutorial materials to study for the test.

The experimental group, which consists of the same group of learners, was introduced to the adaptive learning tool and given a week to use it. A post-test was then administered to assess their performance.

This process was repeated for the second topic to observe any differences in results.

At the end of the study, learners completed a survey to gather their perceptions of the usefulness, satisfaction, and ease of use of adaptive learning tool using the USE survey instrument. The questionnaire items are listed in Table 2.

Table 2 USE Questionnaire Items

Usefulness	Satisfaction	Ease of Use
• Adaptive Learning identifies my gaps and helps me reinforce my learning. • Adaptive Learning helps me to understand and apply the concepts. • I prefer individualised learning paths and focus remedial over the traditional approach.	• I feel more confident and motivated. • I wish it covers more topics.	• It is easy to use. • It is reliable.

RESULTS AND DISCUSSION

Data analysis as shown in Table 3, revealed that adaptive learning improved learning outcomes, with average scores increasing by 16%, passing rate by 20%, and more learners scoring grade B and above. This demonstrates that adaptive learning leads to better performance for learners.

More significantly, learners who scored less than 50% in the pre-test improved their scores by an average of 35.4%. This shows that adaptive learning can help low-performing learners close the performance gap with high-performing learners.

T-tests confirmed a significant difference between pre-test and post-test performance for both topics, with p-values of 0.0011 and 0.0012, respectively. This indicates that adaptive learning is effective in improving learners' performance in both topics.

Table 3. Data Analysis (T-test)

Topic	Tests	No of Students	Mean	Pooled Std Dev	t-value	p-value
Topic 1	Pre-test	77	56.48	35.5	3.12	0.0011
	Post Test	77	74.31			
Topic 2	Pre-test	74	49.04	28.2	3.10	0.0012
	Post Test	74	63.52			

Figure 6 shows the results from a survey conducted at the end of the study to gather the learners' perceptions of the usefulness, satisfaction, ease of learning and ease of use of Brightspace Leap. Learners found adaptive learning useful and easy to use. Over 95% agreed that it helped them understand concepts and apply them. They found learning simpler, easier to understand and more appealing than the traditional learning approaches.

Learners appreciate the immediate feedback that the adaptive tool provides, which helped them identify their knowledge gaps and reinforce their learning independently. They also liked being able to focus on the most effective materials for each learning objective, which helped them clarify uncertainties and build confidence.

As a result, learners felt more confident and motivated to continue their learning journey. More than 80% of the learners preferred individual learning paths and focused remediation over the traditional one-size-fits-all approach. The word cloud in Figure 7 suggests that most learners find adaptive learning helpful, effective, and useful.

Despite the limited scope of this study, which only piloted two topics, learners expressed a desire for adaptive learning to be extended to cover more topics. This feedback suggests that adaptive learning can be a valuable and effective tool for enhancing the learning experience. The results of this research provide evidence in support to the use of adaptive learning in education.

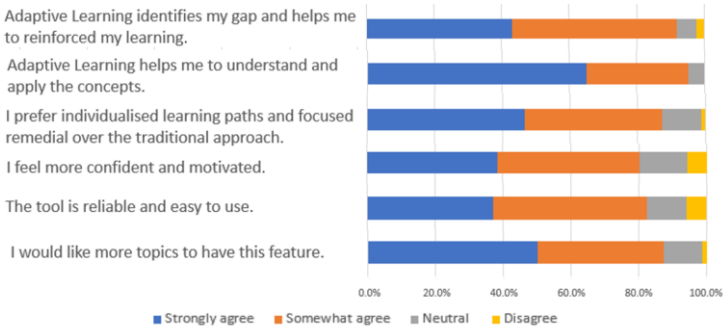

Figure 6. Survey Results

Figure 7. Word cloud on how the learners feel about adaptive learning

Another important aspect of adaptive learning is data analysis. This involves using the data from learners' performance and interactions with the system to identify patterns and trends. This information can then be used to adjust the learning for individual learners, or to identify areas where the curriculum needs to be improved.

Adaptive learning also offers advantages from the teacher's perspective. By generating learning analytics, Brightspace provides valuable feedback that allows teachers to make decisions about their teaching strategies.

Brightspace provides teachers with an activity report (as shown in Figure 8) that displays the viewer rate of each learning objective. A higher viewer rate for a specific learning objective suggests that most learners may be finding that learning objective challenging and may benefit from additional support or clarification. The teacher can then allocate more time during face-to-face lessons to clarify these concepts.

Learning Objective	Path Viewed	Supplemental Viewed	Recommend Reading Views	Question Remediation Views	Time On Page	Last Accessed
Chain Rule	210	41	2	32	1.17:19:58	11/6/2022 5:18:19 AM
Partial Derivatives	78	19	7	21	16:28:45	11/6/2022 4:34:18 AM
View all Activity for "Topic 1.1 LeaP 2"	**288**	**60**	**9**	**53**	**2.09:48:43**	**11/6/2022 5:18:19 AM**

Figure 8. Activity Report

Brightspace also provides teachers with detailed information on individual learners' progress towards the learning objectives, enabling them to track each learner's performance and monitor the materials they have accessed.

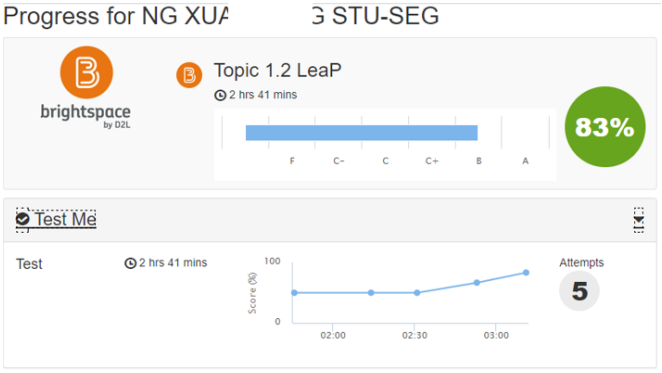

Figure 9. Learner's Progress Report

Figure 10. Learner's Viewing History

By identifying learners who have not made sufficient progress, teachers can provide targeted interventions and support, enabling them to achieve better learning outcomes. For example, teachers could arrange for struggling learners to attend peer tutoring or face-to-face supplementary lessons that target specific areas of difficulty. By leveraging the data generated by Brightspace, teachers can take proactive measures to help these students achieve their learning goals.

Additionally, Brightspace's ability to filter data by class allows teachers to identify the class learning profile and customise their classroom management techniques to better support their learners.

CHALLENGES AND RECOMMENDATIONS

Challenge 1: The Need to Create More Contents for AI-Enabled Adaptive Learning

To implement adaptive learning using Brightspace LeaP, instructors must create sufficient learning content and beef up question banks according to the learning objectives defined. This will allow the AI engine to generate adaptive learning paths with accurate materials.

We curated and adapted the existing content sources such as lecture notes and online resources, ensuring the alignment with specific learning objectives. The resources were chunked into bite-size and made into various formats, including videos, text, audio, and

animations, to meet diverse learning needs. All materials were strategically tagged for machine learning. However, this process can be time-consuming, so it is recommended to start small by implementing adaptive learning on a topical basis.

A comprehensive question bank that encompasses a wide range of question types and difficulty levels was carefully crafted with relevant keywords to enable the AI engine to accurately assess student understanding and identify their knowledge gaps. To beef-up the question bank, high-quality questions were created to align with specific learning objectives. Existing question banks were aggregated and vetted for quality and relevance.

Challenge 2: Addressing the Accuracy of the AI Model

AI-enabled adaptive learning systems require a robust AI engine capable of accurately interpreting student responses, identifying knowledge gaps, and recommending personalised learning paths.

We tackled the challenge of improving AI accuracy by capturing a comprehensive dataset of student interactions through assessments, practice exercises, and self-paced activities. This improves the AI engine's predictive capabilities for precise recommendations of study materials and assessments to pitch the knowledge gaps. Iterative evaluation of study materials driven by their effectiveness in helping the learners improve, along with the number of "likes" awarded by the other learners form a feedback loop, contributing to continuous optimisation of the AI's performance.

Challenge 3: Use of Relatively New Technology for Education

Integrating adaptive learning into the polytechnic's curriculum marked a departure from conventional methods. The risk involved adopting a relatively new technology, untested in the polytechnic educational landscape, and the uncertainties about its reliability, effectiveness, and suitability for mathematics instruction.

We worked closely with the Center for Teaching and Learning Development (CTLD) at Nanyang Polytechnic and the Brightspace developer for technical support. The pilot program involving 86 learners provided valuable hands-on experience, enabling the evaluation of the technology's functionality and effectiveness in an authentic learning environment. The approach not only addressed the uncertainties but also laid the foundation for refining the adaptive learning platform.

To support other educators in embracing adaptive learning, we collaborated with CTLD to organise trainings for teachers. We also shared our experiences and lessons learned through conferences and webinars with other institutions of higher learning and communities to promote personalised learning.

CONCLUSIONS

Adaptive learning benefits both learners and educators.

For learners, adaptive learning improves understanding, engagement, and performance. It is also time-efficient, as learners only focus on what they need to learn. Both statistical and survey results show that adaptive learning is preferred over the traditional one-size-fits-all approach.

For educators, adaptive learning improves teaching effectiveness and identifies areas for curriculum improvement. It is a well-received tool that can be used in most courses.

Adaptive learning is a powerful learner-centric tool that revolutionises the teaching and learning experience. The encouraging results of this investigation encourage educators to use adaptive learning to support learning.

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BIOGRAPHICAL INFORMATION

Cheng Sheau Chin is a senior lecturer at the School of Engineering at Nanyang Polytechnic with over 20 years of experience in teaching and learning. Her main research interests are in education technology and pedagogy, especially the adoption of technology and new practicum model to improve learning outcomes in mathematics and tertiary education. She serves as a member of the review panel for the International Symposium on Advances in Technology Education 2023.

Dr Kong Wai Ming is a Lead Specialist (Computational Analysis) at the Biomedical Engineering and Materials Group, School of Engineering, Nanyang Polytechnic. He holds a doctorate degree in computer science from the Tokyo Institute of Technology. His areas of research include AI, GIS, image processing, and computer graphics. Wai Ming is an innovation evangelist who has a passion for using technology to solve workplace problems. Wai Ming is the project leader of several grant projects, and he has delivered solutions in areas such as human gait analysis, food consumption analysis, barrier routing and navigation solutions for the visually impaired. He has also developed new AR teaching apps to provide fun and interactive learning experiences for students. Wai Ming believed in borderless collaboration to deliver better technology solutions for the problems we faced today. Wai Ming is in the organising committees for many international conferences and is actively involved in promoting innovation and research in healthcare and many areas.

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