

# **Adaptive Learning System for Professional Development Toolkit**

Version 1.0

<b>Principal Investigator (PI)</b>	Associate Professor Goh Yang Miang
<b>Co-PI</b>	Assistant Professor Juliana Tay
<b>Researchers</b>	Dr Punyawee Anunpattana Ms Sufiana Safiena Ms Hu Xinpings Mr Wesley Teoh Mr Jiang Chen

**Centre for Project and Facilities Management**  
Department of the Built Environment  
National University of Singapore

## **Disclaimer**

- i. This document (“Toolkit”) assists users in developing and adopting an adaptive learning system (ALS). Users are encouraged to adapt the Toolkit according to the objectives of their learning programmes and the learners’ needs.
- ii. Users should exercise discretion when applying this Toolkit. To the extent permitted by law and unless caused by the National University of Singapore (NUS)’s negligence, NUS will not be held liable for any loss or damage sustained by the users of this Toolkit.
- iii. NUS reserves all rights to this Toolkit. Any unauthorised duplication or distribution of this Toolkit infringes NUS’s intellectual property rights.

## **Table of Contents**

Disclaimer.....	ii
Table of Contents .....	iii
List of Figures.....	v
List of Tables .....	vi
1    Introduction .....	1
1.1    Adaptive Learning (AL) and Adaptive Learning System (ALS).....	1
1.2    Importance of ALS in Professional Development (PD).....	2
1.3    Key Considerations for Designing ALS for PD .....	2
1.4    Structure of this Toolkit .....	5
1.5    Terms of Usage .....	7
2    Adaptive Learning Framework.....	8
2.1    Content Component.....	8
2.2    Learner Component.....	10
2.3    Adaptive Features Component .....	11
2.4    Development, Integration and Other Considerations.....	13
3    Knowledge Unit Recommender (KUR).....	16
3.1    Overview and Features of KUR.....	16
3.2    Implementation Guidelines for KUR.....	18
3.3    Best Practices and Considerations for KUR .....	38
4    Adaptive Quiz (AQ) .....	40
4.1    Overview and Features of AQ .....	40
4.2    Implementation Guidelines for AQ.....	41
4.3    Best Practices and Considerations for AQ .....	50
5    Personalised Feedback (PF).....	53
5.1    Overview and Features of PF.....	53
5.2    Implementation Guidelines for PF .....	56
5.3    Exercise: Creating Your PF .....	67
5.4    Considerations for PF .....	69

6 Conclusion .....	71
6.1 Recommended Reading.....	71
6.2 Acknowledgements .....	73
References.....	74
Annex A: Checklists.....	77
Annex B: Sample LLM Prompts.....	89

## **List of Figures**

Figure 1 Key considerations based on adult learner characteristics .....	2
Figure 2 The different phases of the study .....	6
Figure 3 Adaptive learning framework and its components.....	8
Figure 4 Ranking of adaptive features (using a 5-point Likert scale) .....	11
Figure 5 Example of LTI integration process.....	14
Figure 6 Example of KUR workflow integrated with LLM .....	16
Figure 7 Developed the KU matrix based on process group and knowledge areas ...	27
Figure 8 Example of Cell 16 containing multiple KUs (i.e., one video is one KU).....	28
Figure 9 Grouping of multiple KUs into one module under Initiating Process Group in Canvas .....	29
Figure 10 Sample Canvas page design with the recommended metadata.....	30
Figure 11 Our KUR workflow using LLM to generate learning paths .....	35
Figure 12 Example of AQ system workflow integrated with LMS .....	40
Figure 13 Example of the database schema for AQ .....	41
Figure 14 Snippet from our quiz bank.....	44
Figure 15 User interface (UI) of our AQ.....	48
Figure 16 Various setting options in our AQ portal for the learners to take control of their learning.....	49
Figure 17 Example of PF workflow integrated with LMS (*optional components).....	53
Figure 18 Example of PF generated and sent to learner's Canvas inbox .....	65
Figure 19 Example questions to set PF preference for each learner.....	66

## **List of Tables**

Table 1 List of suggested experts.....	15
Table 2 Key components of the KUR system.....	16
Table 3 Suggested data to capture when building learner profiles .....	18
Table 4 Example of our pre-questionnaire items to build a learner profile .....	20
Table 5 Examples of learning objectives.....	22
Table 6 Our overall LOs for the course.....	23
Table 7 LOs of Cell 1 (Initiating Integration Management).....	24
Table 8 LO of Cell 22 (Executing Risk Management).....	24
Table 9 Example of a KU matrix .....	25
Table 10 Sample list of our lecture videos categorised by modules and cells.....	28
Table 11 List of standard recommendation algorithms .....	31
Table 12 Our LLM prompt for generating personalised learning paths .....	36
Table 13 Output from the LLM prompt .....	37
Table 14 Suggested parameters for the database schema for AQ .....	42
Table 15 Our quiz bank tracker to determine how many questions are required .....	45
Table 16 Example of our LLM prompt to generate items for quiz bank.....	45
Table 17 Common algorithms to select the quiz questions in AQ .....	46
Table 18 Examples of learners' data you can export through your LMS .....	56
Table 19 Sample assignment feedback template using LLM .....	59
Table 20 Key metrics to track performances.....	63

## 1 Introduction

The *Adaptive Learning System for Professional Development Toolkit* ("Toolkit") provides course developers, instructional designers, and learning administrators with a structured framework for designing and implementing adaptive learning strategies in professional development (PD) settings.

This Toolkit is developed as part of the research project "**Improving Professional Development through an Intelligent Adaptive Learning Approach: An In-Depth Study on Construction Project Managers**" and supported by SkillsFuture Singapore under the Workforce Development Applied Research Fund (WDARF) grant [GA21-04].

### 1.1 Adaptive Learning (AL) and Adaptive Learning System (ALS)

Adaptive learning (AL) is an educational approach that tailors the learning experience to the individual's needs by dynamically adjusting content, assessments, and feedback based on their performance and interactions (Corbalan et al., 2008; Essa et al., 2023; Fernandes et al., 2023; Mavroudi et al., 2018). An adaptive learning system (ALS) is the technological framework that enables this personalised approach, utilising data analytics, algorithms, and real-time feedback to guide learners through a customised educational journey (Hwang et al., 2020; Kurilovas et al., 2015; Pliakos et al., 2019; Xie et al., 2019).

In professional development (PD), ALS foster self-regulated learning by allowing professionals to monitor their progress, take ownership of their learning journey, and receive timely and targeted support. By leveraging technology and artificial intelligence (AI), ALS enhances flexibility, improves learning outcomes, and enables professionals to upskill efficiently while balancing work and personal commitments (Chou et al., 2018; Moreno-Guerrero et al., 2020).

## 1.2 Importance of ALS in Professional Development (PD)

Adult learners bring diverse experiences and varying levels of expertise, meaning that a one-size-fits-all teaching and learning approach is often ineffective (Knowles et al., 2020). AL addresses this challenge by ensuring that each professional receives learning content relevant to their prior knowledge, industry, and role-specific needs (Chen, 2014).

It must also focus on closing skill gaps and supporting career progression (Merriam, 2001; Mezirow & Taylor, 2009). Finally, it must deliver content efficiently by reducing unnecessary material and concentrating on the essentials. By aligning training with real-world professional challenges, ALS enhances engagement, optimises learning efficiency, and improves long-term retention.

## 1.3 Key Considerations for Designing ALS for PD

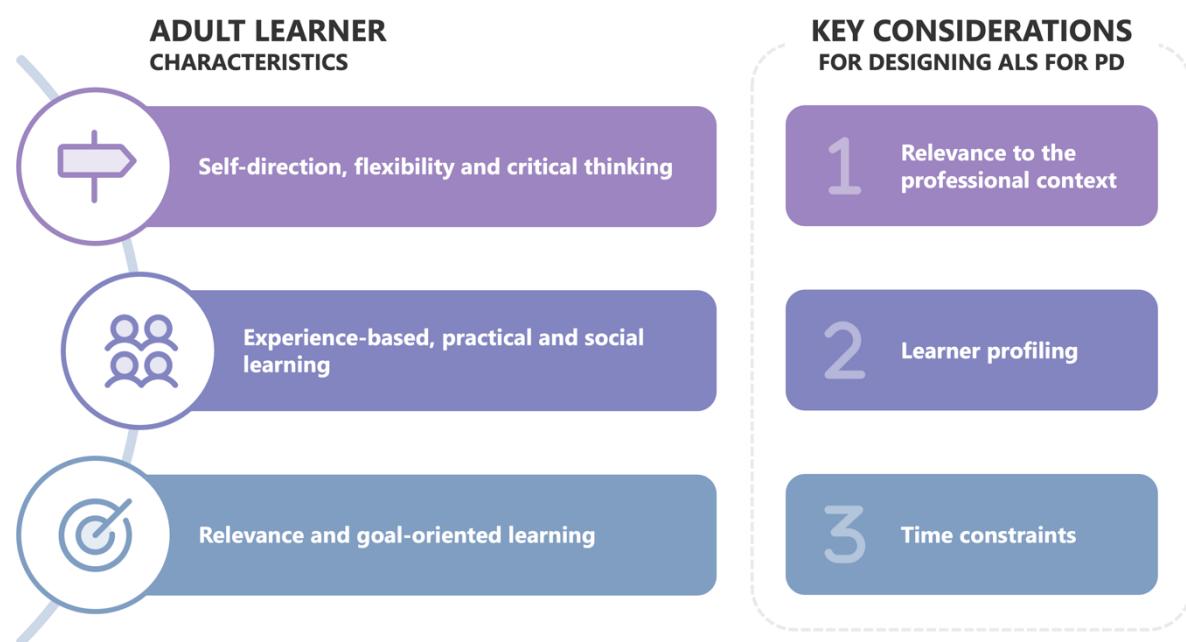


Figure 1 Key considerations based on adult learner characteristics

Adult learners and professionals have distinct characteristics that set them apart from traditional students, as illustrated in Figure 1. By acknowledging their diverse life experiences and unique learning needs, PD courses can be designed to foster greater engagement and effectiveness. Here are three key considerations:

## 1. Relevance to the professional context

Adult learners value autonomy and prefer to take control of their educational journey (Knowles et al., 2020). They integrate new knowledge with their existing personal, professional, and social experiences, seeking practical applications that address real-world challenges (Merriam, 2001). They are goal-oriented and benefit most from problem-solving activities with direct workplace relevance (Chen, 2014). PD courses should support self-regulated learning by allowing for continuous refinement of materials based on evolving industry needs.



### Considerations

#### 1 Real-world application

The content should be authentic and mirror workplace challenges, decisions, and tasks to ensure immediate application on the job.

#### 2 Industry-specific content

Learning materials should be regularly updated to reflect current trends, policies, and best practices.

#### 3 Learner autonomy

Provide opportunities for learners to choose topics, projects, or assessments that align with their professional goals.

## 2. Learner profiling

Unlike formal education students, PD program professionals come from diverse backgrounds with varying expertise and learning needs (Leow et al., 2022). A one-size-fits-all approach is often ineffective; what is essential for one learner may be irrelevant or overly complex for another. Tailoring content through adaptive learning strategies and providing constructive feedback can help professionals reflect on their progress, adjust their plans, and improve their performance.



### Considerations

#### 1 Needs-based customisation

Offer personalised learning paths based on prior knowledge, job roles, or career aspirations, and use assessments or AI-driven algorithms to adjust content difficulty based on learner performance.

#### 2 Constructive feedback

Provide actionable feedback to guide learners in refining their skills and approaches.

#### 3 Collaborative learning

Encourage peer discussions, mentorships, and networking to facilitate knowledge-sharing.

### 3. Time constraints

Balancing work, family responsibilities, and personal commitments make rigid training schedules impractical for professional learners (Knowles et al., 2020). To enhance accessibility and efficiency, PD programs should offer flexible, modular content that allows learners to progress at their own pace. Asynchronous learning options, bite-sized lessons, and on-demand resources can further support busy professionals in integrating learning into their daily routines (Evans et al., 2014; Gagnon & Packard, 2012).

 Considerations
<b>1 Asynchronous, modular and flexible learning formats</b> Offer self-paced, hybrid, or microlearning modules to accommodate different schedules and enable learners to access materials anytime, reducing dependency on fixed schedules.
<b>2 Bite-sized content</b> Deliver information in short, focused segments to maximise retention and minimise time commitment.

#### 1.4 Structure of this Toolkit

This Toolkit is a comprehensive, step-by-step guide for implementing ALS in PD courses. It provides course developers with a structured approach to integrating adaptive features for a personalised learning experience. Drawing from extensive research and real-world applications, it highlights key learning points, best practices, and proven strategies to enhance engagement and optimise learning outcomes.

Note that this Toolkit highlights specific examples to illustrate key AL features, drawing on our direct experience developing and refining the ALS. These examples provide practical insights into how the system addresses industry gaps and enhances the learning experience for adult learners. The study follows a structured approach across three phases, as illustrated in Figure 2.

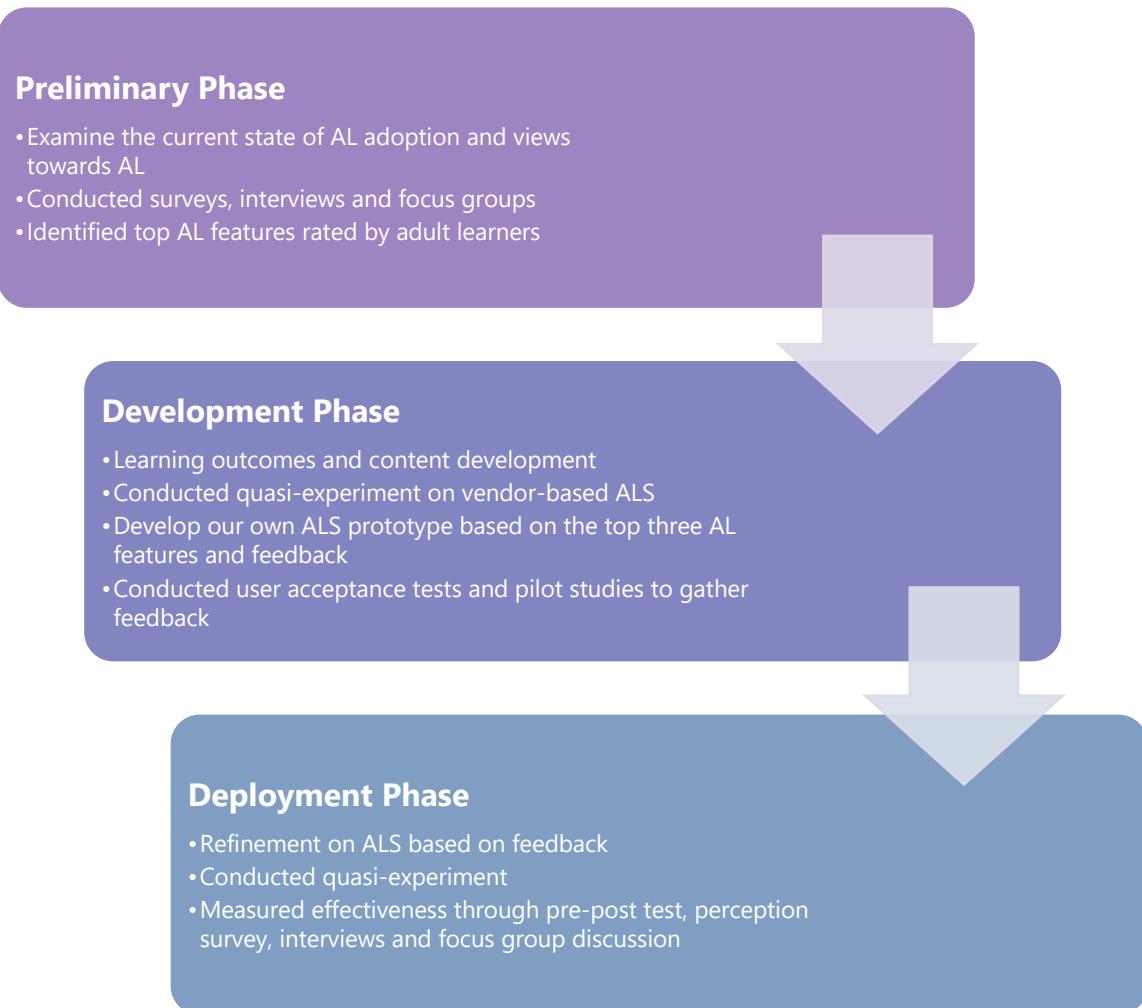


Figure 2 The different phases of the study

We developed an asynchronous online course for construction and built environment professionals seeking to enhance their project management (PM) skills. The course caters to many professionals, including architects, engineers, existing project managers, safety personnel, and anyone looking to upskill in PM. It introduces the fundamentals of PM by introducing the five process groups and ten knowledge areas. The online course was designed for professionals to learn independently while gaining practical and industry-relevant knowledge.

Subsequent sections introduce the core adaptive features, key components, integration requirements, implementation examples, essential guidelines, and checklists ([Annex A](#)). Although we used the [Canvas](#) learning management system (LMS) for our study, the findings from this Toolkit can be applied to other systems, such as Moodle, Blackboard, and other corporate training platforms.

## 1.5 Terms of Usage

All guidelines, examples and checklists ([Annex A](#)) listed in this Toolkit are free for all to use. NUS reserves the right to edit, update or replace any part of the content within this Toolkit at any time. Proper attribution is required for others to distribute, display, perform the work, and make and distribute derivative works based on it.

Please refer to the below on how to cite this Toolkit.



### Cite Us (APA 7<sup>th</sup> Edition)

**Anunpattana, P., Hu, X., Safiena, S., Tay, J., Goh, Y. M. (2025). *Adaptive learning system for professional development toolkit*. National University of Singapore (NUS). <https://github.com/NUS-DBE/ALS-Toolkit>**



**General correspondence:** [bdgbox34@nus.edu.sg](mailto:bdgbox34@nus.edu.sg)

**KUR and AQ specific queries:** [punyawee@nus.edu.sg](mailto:punyawee@nus.edu.sg)

**PF specific queries:** [xinping@nus.edu.sg](mailto:xinping@nus.edu.sg)

## 2 Adaptive Learning Framework

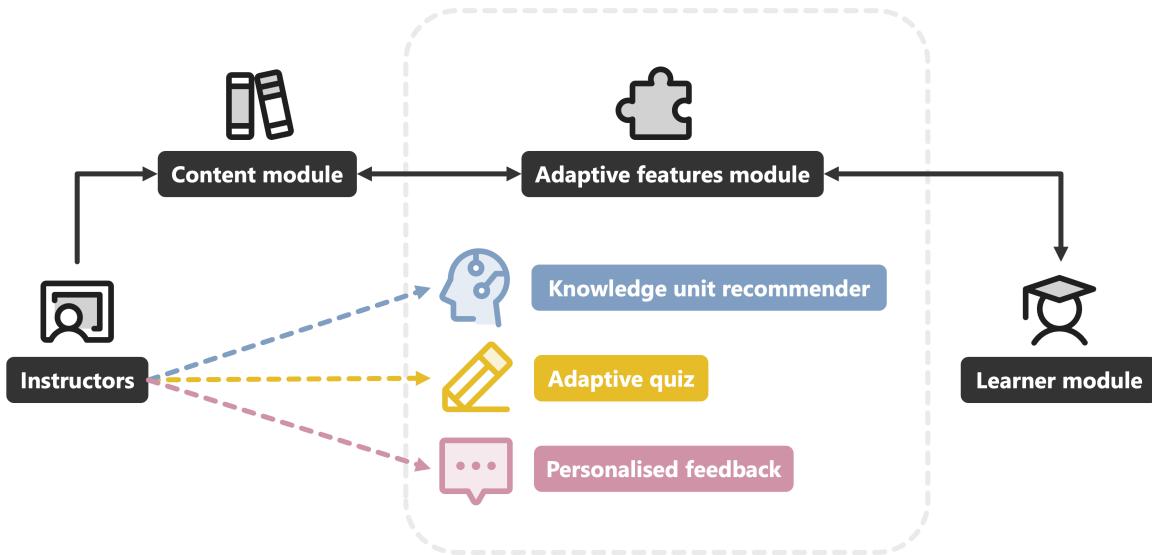


Figure 3 Adaptive learning framework and its components

The adaptive learning framework is the foundation for designing and implementing an effective ALS for PD. It incorporates essential components that dynamically adjust learning pathways based on individual learners' needs, preferences, and progress. As illustrated in Figure 3, the framework consists of three (3) main components: content, learner, and adaptive features.

### 2.1 Content Component

The content component serves as a repository for learning materials, including instructional content, exercises, and assessments. It engages with instructors and adaptive features to guarantee that materials remain relevant and personalised. Learning resources are organised for flexible access and dynamically tailored according to the learner's progress and requirements.

Key features	
1	<b>Modular structure</b> Content is divided into smaller, manageable knowledge units (KUs) for flexibility and personalisation.

## 2 Varied formats

Includes text, videos, quizzes, simulations, and interactive tasks to accommodate different learning styles.

## 3 Real-world application

Materials align with industry standards and workplace challenges to ensure practical relevance.

## 4 Dynamic content updates

Content evolves to reflect the latest knowledge, policies, and best practices.



## Considerations

### 1 Personalisation

Learning materials should be adaptable to different proficiency levels and professional backgrounds.

### 2 Engagement

Interactive elements such as case studies and hands-on exercises should be incorporated to enhance participation.

### 3 Accessibility

Content must be available across multiple devices and formats for ease of access.

### 4 Assessment integration

Regular quizzes, self-checks, and feedback loops should be included to track understanding and progress.

## 2.2 Learner Component

The learner component represents the end-user (i.e., the learners), engaging with personalised content, adaptive quizzes, and interactive materials. Learner interactions generate feedback, which the adaptive system continuously processes to refine and optimise the learning experience. This iterative process ensures that content remains dynamic and responsive to individual progress.

 Key features
<b>1 Personalised learning pathways</b>
Content adapts based on prior knowledge, skills, and learning goals.
<b>2 Self-paced learning</b>
Learners progress at their speed, balancing professional and personal commitments.
<b>3 Engagement tracking</b>
Learning activities and performance data are continuously monitored to optimise learning experiences.
<b>4 Feedback and reflection</b>
Constructive feedback is provided to help learners reflect on their progress and adjust strategies.

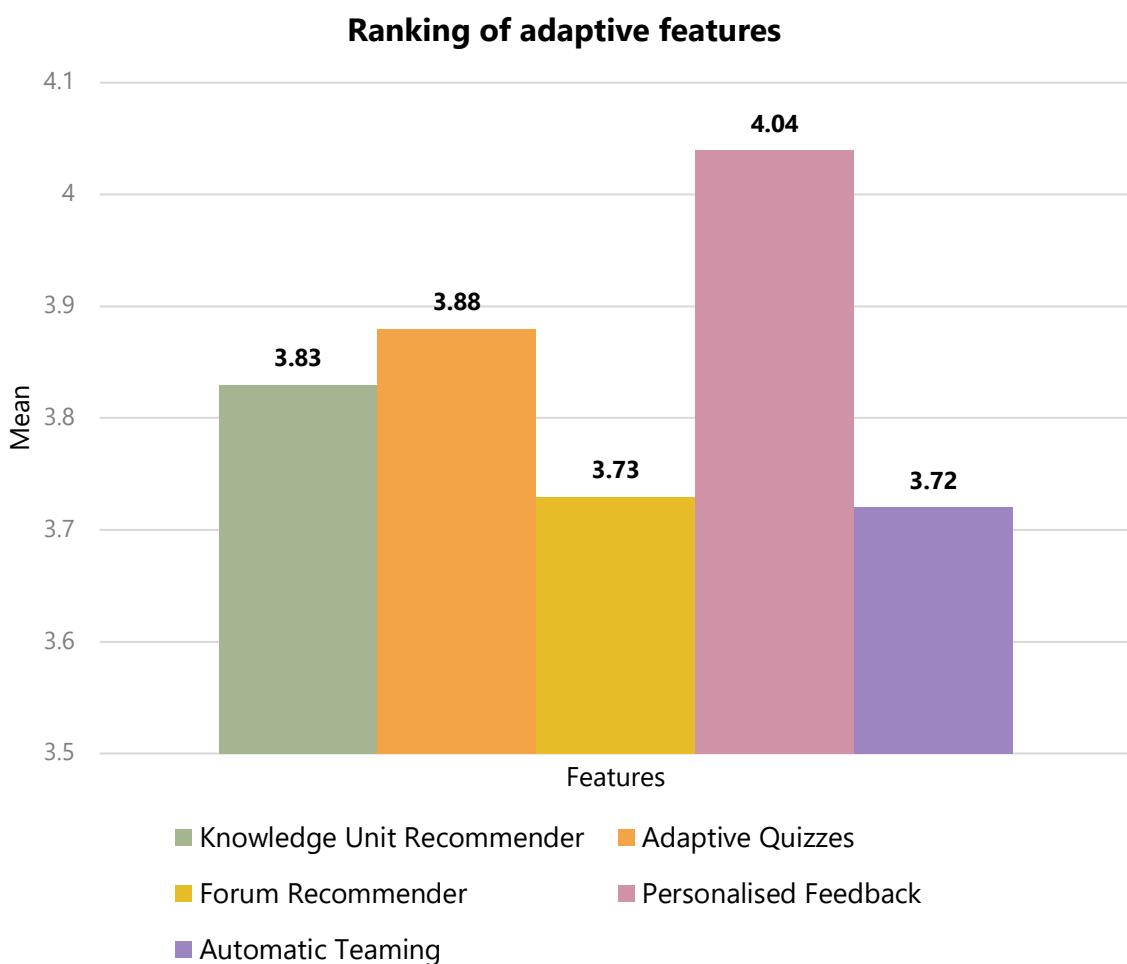
 Considerations
<b>1 Diverse learning needs</b>
Learners come from different backgrounds and require varied levels of complexity in content delivery.
<b>2 Autonomy and motivation</b>
Self-directed learning should be encouraged through interactive and goal-oriented tasks.

### 3 Peer and instructor interaction

Opportunities for discussion, collaboration, and mentoring enhance learning experiences.

## 2.3 Adaptive Features Component

The adaptive features component is the intelligence behind personalised learning. It analyses data from the learner component and matches it with content to generate customised learning paths. Adaptive algorithms, learning analytics, and real-time recommendations ensure learners receive the most suitable materials and activities based on their performance, preferences, and learning styles.



*Figure 4 Ranking of adaptive features (using a 5-point Likert scale)*

Although many adaptive features are available on the market, this Toolkit focuses on three core adaptive features: the Knowledge Unit Recommender (KUR), Adaptive Quiz (AQ), and Personalised Feedback (PF). These selected features were based on our questionnaire survey, which surveyed more than 300 adult learners and trainers in Singapore (Figure 4).

 Key features
<b>1 Dynamic content adaptation</b>
Learning materials adjust in real time based on learner performance and engagement.
<b>2 Personalised recommendations</b>
AI-driven insights suggest relevant content, activities, or additional resources.
<b>3 Adaptive assessments</b>
Question difficulty and learning pathways are modified based on learner responses and progress.
<b>4 Data-driven insights</b>
Learning analytics track patterns to refine content, improve delivery, and enhance learner success.

 Considerations
<b>1 Scalability and flexibility</b>
The system must adapt to different learning environments and user needs.
<b>2 Timely and relevant feedback</b>
Learners should receive immediate responses to quizzes and tasks to reinforce understanding.

**3 Privacy and data security**

Sensitive learner data must be protected while leveraging analytics for optimisation.

**4 Continuous improvement**

Adaptive algorithms should be regularly updated to enhance accuracy and effectiveness.

## 2.4 Development, Integration and Other Considerations

Developing and integrating an ALS requires a systematic approach to ensure seamless functionality, scalability, and effectiveness. Additionally, consideration of integration challenges, system compatibility, and expert collaboration is crucial to a successful deployment. This section outlines key aspects of ALS development, integration, and other important considerations.

### 1. System Architecture and Infrastructure

A scalable and secure infrastructure is crucial for effectively deploying an ALS. The system should support cloud-based, on-premises, and hybrid models to suit organisational needs. Cloud-based solutions offer remote access, automatic updates, and scalability, while on-premises setups provide greater data security and compliance. A hybrid approach combines both, balancing flexibility and control.

The system must handle high user loads and real-time data processing to ensure stability and efficiency. Regular monitoring, performance optimisation, and updates are essential to maintaining a seamless learning experience and keeping up with evolving technological and educational demands.

### 2. Data Management and Security

A strong data governance framework is crucial for ethically handling learner data. Compliance with regulations like GDPR and other data privacy laws must be a priority to protect personal and educational information. Secure data management practices, such as encryption, access controls, and anonymisation, help prevent unauthorised access and data breaches.

### 3. Interoperability, Integration and System Considerations

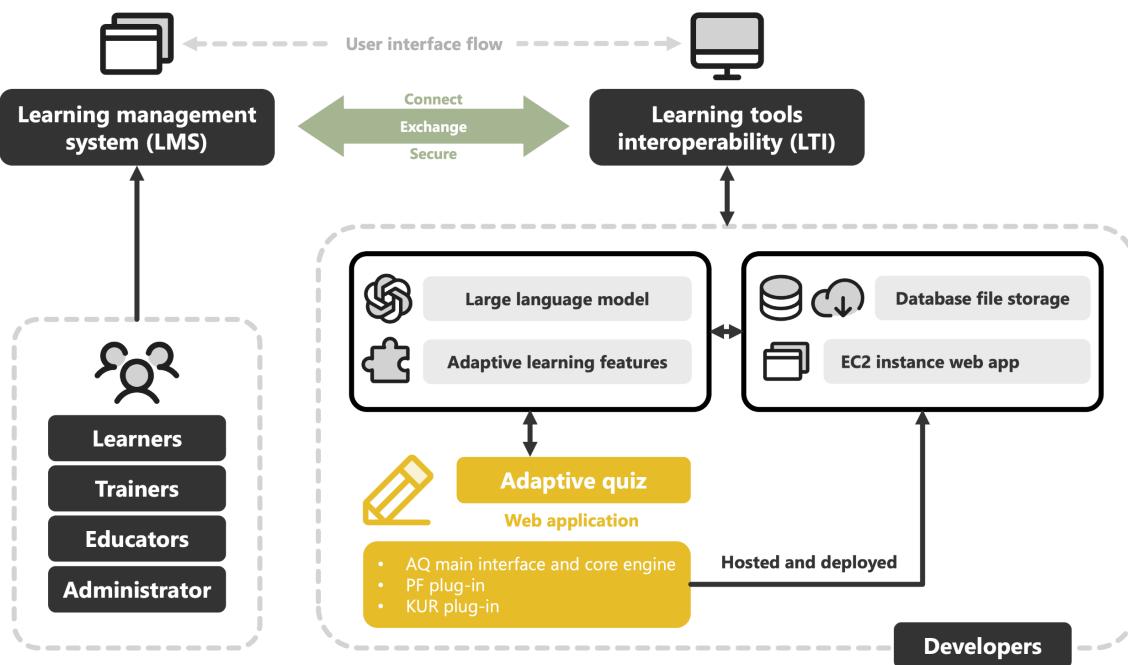


Figure 5 Example of LTI integration process

For an ALS to function effectively, seamless integration with existing LMS platforms such as Moodle, Blackboard, Canvas, and other corporate training systems is essential. This integration is achieved through Learning Tool Interoperability (LTI), a standard that enables smooth communication among various educational tools. This allows adaptive features to operate cohesively within the learning ecosystem. Learn more about the current LTI version (v1.3) integration [here](#).

APIs, standardised protocols, and secure data transmission should facilitate interoperability, allowing adaptive learning tools to exchange information efficiently. Institutions should also assess whether their digital ecosystems, including on-premises and cloud-based infrastructures, support the scalability and flexibility required for ALS implementation.

### 4. User Experience and Accessibility

A well-designed ALS should focus on user engagement, easy navigation, and accessibility to support diverse learners. Intuitive interfaces, interactive elements, and smooth navigation enhance engagement and retention. Compliance with accessibility standards like Web Content Accessibility Guidelines (WCAG) 2.1 is essential to support learners with disabilities. Features like captioned videos,

adjustable font sizes, and keyboard navigation improve inclusivity. A responsive design ensures compatibility across desktops, tablets, and mobile devices, allowing flexible access. Regular usability testing and user feedback help refine the system, optimising the learning experience.

## **5. Expert Collaboration and Continuous Improvement**

A successful ALS requires collaboration between course developers, engineers, LMS specialists, and industry experts. Clear communication and structured workflows ensure it meets technical and educational needs. Institutions should establish protocols for updates, bug fixes, and performance monitoring. Real-time tracking helps identify engagement trends and areas for improvement.

Ongoing refinement through feedback, analytics, and technology keeps the ALS effective. Regular updates to algorithms, content, and user experience maintain relevance. Expert input is also crucial for improving AI models and recommendation accuracy. Table 1 provides an overview of suggested experts involved in the implementation of ALS.

*Table 1 List of suggested experts*

<b>Objectives</b>	<b>Suggested experts</b>
<b>Development of learning objectives and content</b> Establish the objectives and learning materials that must be met upon completion of the course	<ul style="list-style-type: none"> <li>• Course developers</li> <li>• Industry experts</li> <li>• Institution representative</li> </ul>
<b>Development of adaptive features</b> Establish the requirements for adaptive features and development of the algorithm	<ul style="list-style-type: none"> <li>• Course developers</li> <li>• Software developers</li> <li>• Research engineers</li> <li>• Industry experts</li> </ul>
<b>Integration to the LMS</b> Establish the requirements and solutions for integrating adaptive features into LMS	<ul style="list-style-type: none"> <li>• Course developers</li> <li>• LMS developers and specialists</li> <li>• Institution representative</li> </ul>

### 3 Knowledge Unit Recommender (KUR)

#### 3.1 Overview and Features of KUR

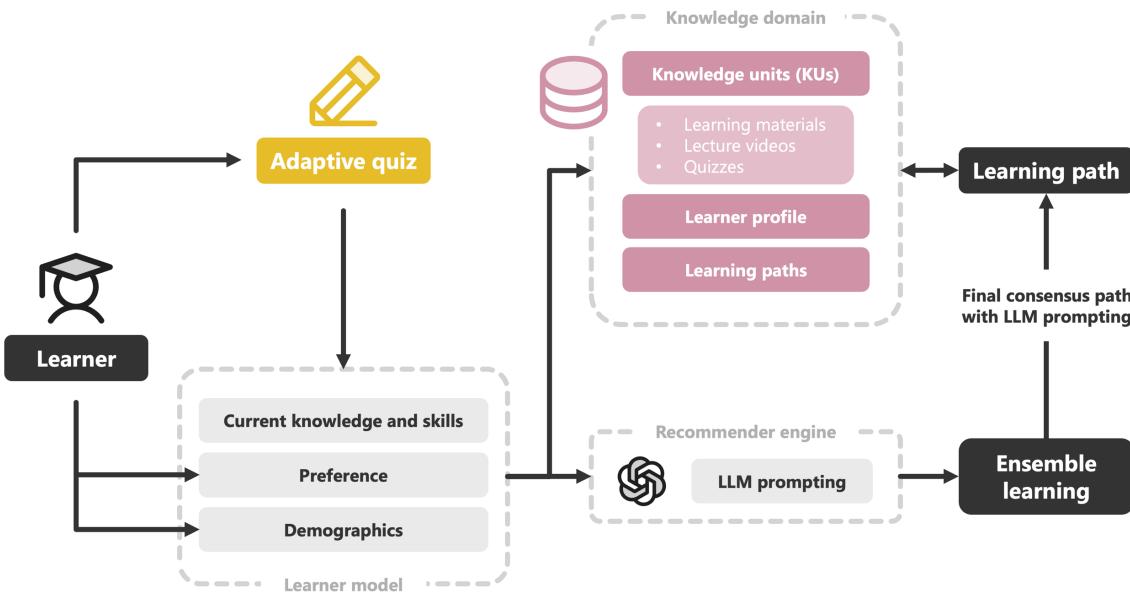


Figure 6 Example of KUR workflow integrated with LLM

Knowledge Unit Recommender (KUR) is an intelligent system designed to enhance personalised learning experiences by recommending relevant learning materials, concepts, or skills (referred to as knowledge units (KUs)). These recommendations are based on the learner's past interactions, preferences, current skill level, and learning goals. The KUR system workflow integrates multiple components to generate personalised learning paths, as shown in Table 2.

Table 2 Key components of the KUR system

Component	Description
<b>Learner model</b>	<ul style="list-style-type: none"> <li>Captures learner attributes such as current knowledge, proficiencies, learning preferences, and demographic details.</li> <li>Learners' profiles are stored in a database and will be continuously updated based on their interaction with the system.</li> </ul>

<b>Knowledge domain</b>	<ul style="list-style-type: none"> <li>• A structured repository of knowledge units (KUs), which include learning materials like video lectures, quizzes, assignments, and lecture handouts.</li> <li>• These KUs are tagged with metadata such as learning objectives, estimated completion time and difficulty level.</li> </ul>
<b>Recommender engine</b>	<ul style="list-style-type: none"> <li>• Employs AI-driven methodologies to generate personalised learning pathways.</li> </ul>
<b>Ensemble learning</b>	<ul style="list-style-type: none"> <li>• It employs machine learning (ML) techniques that combine multiple models to refine the learning path generated by the recommender engine.</li> </ul>



## Key features of our KUR workflow

### 1 Personalisation and adaptive learning paths

Tailor recommendations based on a learner's background, skill level, and learning goals, and adjust learning sequences dynamically based on learner progress and assessment results.

### 2 AI-driven recommendations

Examples of the most common methods are:

- *Content-based filtering*: Recommends materials like what the learner has previously engaged with
- *Collaborative filtering*: Suggests content based on what other learners with similar profiles have accessed
- *Hybrid models*: Uses a combination of filtering techniques for more refined recommendations

### 3 Knowledge graphs and content mapping

Organises learning resources into structured knowledge units (KUs) and ensures a logical learning progression through interconnected concepts.

### 3.2 Implementation Guidelines for KUR

Several key components and methodologies must be established to implement KUR effectively. In this section, we illustrate our development approach. While our methodology has proven to be the most suitable within our context, it is not the only viable approach. We encourage you to modify or adapt these methods to best align with the unique requirements of your PD course.

#### 1. Building comprehensive learner profiles

A learner profile forms the foundation for KUR to offer personalised learning experiences. A well-structured learner profile captures the learner's essential attributes, ensuring that recommendations align with their current knowledge, skill gaps, professional role, and learning preferences. It should be established at the beginning of the course development process. Developing a comprehensive learner profile involves collecting, analysing, and continuously updating three key categories of data, as shown in Table 3.

*Table 3 Suggested data to capture when building learner profiles*

Category	Data and methods
<b>Demographics and professional background</b> Helps determine the suitability of the content for the learner by aligning recommendations with industry standards and career progression to support specific job functions	<b>Key data to capture:</b> <ul style="list-style-type: none"> <li>• Job title and industry</li> <li>• Years of experience</li> <li>• Education level and certifications</li> </ul> <b>Methods:</b> <ul style="list-style-type: none"> <li>• Questionnaire</li> </ul>

<p><b>Learning preferences and interests</b></p> <p>Different professionals engage with content differently</p>	<p><b>Key data to capture:</b></p> <ul style="list-style-type: none"> <li>• Preferred learning format (e.g., video, reading, quizzes, case studies, or hands-on activities)</li> <li>• Preferred course structure (e.g., self-paced, guided learning)</li> <li>• Topic of interests (i.e., Should be able to rank topics based on priority, ensuring that the system suggests the most relevant KU first)</li> <li>• Availability and time constraints (i.e., should recommend content that fits into their schedule)</li> </ul> <p><b>Methods:</b></p> <ul style="list-style-type: none"> <li>• Questionnaire</li> </ul>
<p><b>Knowledge level and baseline assessment</b></p> <p>Determine the learner's level or "starting point" and sequence of knowledge units to prevent redundancy by ensuring learners focus on areas where they need improvement</p>	<p><b>Key data to capture:</b></p> <ul style="list-style-type: none"> <li>• Pre-assessment scores <ul style="list-style-type: none"> <li>◦ <i>Beginner</i>: Requires foundational modules</li> <li>◦ <i>Intermediate</i>: Can start at a mid-level course</li> <li>◦ <i>Advanced</i>: Can skip basic modules and move to expert-level content</li> </ul> </li> <li>• Self-evaluation ratings</li> <li>• Past quiz results</li> <li>• Course completions</li> <li>• Engagement patterns</li> </ul> <p><b>Methods:</b></p> <ul style="list-style-type: none"> <li>• Questionnaire</li> <li>• Baseline test</li> <li>• Historical learning records</li> </ul>

A learner's profile should develop throughout the course. Real-time updates and adaptive adjustments ensure that recommendations stay relevant. If a learner encounters difficulty with an assessment, the system can modify their learning path by suggesting extra practice exercises or alternative explanations. Similarly, if learners often skip topics, the system can deduce their preferences and adapt accordingly.

Incorporating learner feedback into the recommendation process also aids in refining future learning paths, ensuring the content remains engaging and valuable.



## HOW WE IMPLEMENT IN OUR ALS PD COURSE

Before our user testing sessions, pilots, and quasi-experiments, we ask our learners to complete a pre-questionnaire to develop their learner profiles. The pre-questionnaire gathers information about their demographics, professional backgrounds, and learning preferences.

*Table 4 Example of our pre-questionnaire items to build a learner profile*

<b>Section 1: Participant Information</b>		
Gender:	<input type="checkbox"/> Female <input type="checkbox"/> Male	<input type="checkbox"/> Prefer not to answer
Highest Qualification:	<input type="checkbox"/> GCE O Levels <input type="checkbox"/> GCE A Levels/ Diploma <input type="checkbox"/> Bachelors	<input type="checkbox"/> Masters <input type="checkbox"/> Doctoral <input type="checkbox"/> Others: _____
What is your discipline or major of your highest qualification?		
How long have you worked in the industry?	<input type="checkbox"/> < 1 year <input type="checkbox"/> 1 – 5 years <input type="checkbox"/> 6 – 10 years	<input type="checkbox"/> 11 – 15 years <input type="checkbox"/> 16 – 20 years <input type="checkbox"/> > 20 years
What is your role in the construction and the built environment industry?		
What is your company name?		
What is your position/ title in your company?		
How many projects have you managed or been heavily involved in?	<input type="checkbox"/> 0 <input type="checkbox"/> 1 – 5 <input type="checkbox"/> 6 – 10	<input type="checkbox"/> 11 – 15 <input type="checkbox"/> 16 – 20 <input type="checkbox"/> > 20

## Section 2: Experiences in Adaptive Learning

Do you have experience with adaptive learning for professional development?	<input type="checkbox"/> Yes <input type="checkbox"/> No
If the answer to the previous question is yes, how often do you engage in online learning courses or training activities?	<input type="checkbox"/> Yearly <input type="checkbox"/> Monthly <input type="checkbox"/> Weekly <input type="checkbox"/> Daily <input type="checkbox"/> Rarely
Do you prefer online or in-person learning environments or a combination of both (hybrid)?	<input type="checkbox"/> Online <input type="checkbox"/> In-person <input type="checkbox"/> Both
Do you have access to the necessary technology (e.g., computer, internet) to participate in online learning activities?	<input type="checkbox"/> Yes <input type="checkbox"/> No

## Section 3: Learning Preference

Please rank the following process groups according to your learning preferences:

- [1] Initiating Process Group
- [2] Planning Process Group
- [3] Executing Process Group
- [4] Monitoring and Controlling Process Group
- [5] Closing Process Group

Please rank the following knowledge areas according to your learning preferences:

- [1] Integration Management
- [2] Scope Management
- [3] Schedule Management
- [4] Cost Management
- [5] Quality Management
- [6] Resource Management
- [7] Communication Management
- [8] Risk Management
- [9] Procurement Management
- [10] Stakeholder Management

— END OF OUR IMPLEMENTATION EXAMPLE —

## 2. Developing the learning objectives (LOs)

Clear learning objectives are essential in KU development. They guide content creation and ensure alignment with learning outcomes. They help learners understand their goals and keep learning focused and relevant. Each KU should have specific, measurable, and practical objectives to provide professionals with applicable knowledge while avoiding unnecessary content.

We recommend aligning LOs with Bloom's Taxonomy to support effective learning and skill development. Some examples are shown in Table 5. This structured approach helps learners build foundational knowledge, apply skills, and develop critical thinking.

*Table 5 Examples of learning objectives*

 Learning objectives
<ul style="list-style-type: none"> <li>• Define the five project lifecycle phases and outline their key deliverables.</li> <li>• Identify three key leadership styles and explain how each can be applied to a workplace scenario.</li> </ul>
 Considerations
<p><b>1 Structure and align your LOs with Bloom's Taxonomy</b></p> <p>Bloom's Taxonomy is a widely recognised framework for structuring LOs to facilitate effective learning and skill development. It categorises cognitive learning into six levels, progressing from basic knowledge recall to higher-order thinking and problem-solving. Learn more about Bloom's Taxonomy in the <a href="#">Recommended Reading</a>.</p>



## HOW WE IMPLEMENT IN OUR ALS PD COURSE

We developed LOs based on each KU to ensure a structured and targeted learning experience. These objectives align with industry standards and professional competencies, guiding learners toward achieving practical project management skills.

*Table 6 Our overall LOs for the course*

Course learning objectives
<p><b>At the end of the course, learners should be able to:</b></p> <ul style="list-style-type: none"> <li>• Explain the five phases of the predictive project management life cycle and the ten project management knowledge areas.</li> <li>• Develop key project initiation documents, including the project charter, assumption log, and stakeholder register.</li> <li>• Create a comprehensive project management plan for scope, schedule, cost, quality, resources, communications, stakeholder engagement, risk, and procurement management.</li> <li>• Demonstrate how to implement project execution processes, such as Directing and Managing Project Work, Managing Project Knowledge, Managing Quality, Acquiring Resources, Developing and Managing Teams, Managing Communications, Implementing Risk Responses, Conducting Procurements, and Managing Stakeholder Engagement.</li> <li>• Apply project monitoring and controlling processes, including work performance reports, earned value management metrics, integrated change control, scope validation, and controls for schedule, cost, quality, resources, procurement, communications, risks, and stakeholder engagement.</li> <li>• Execute project closing activities by preparing formal customer acceptance, final project reports, lessons learned registers, and conducting project closure meetings.</li> </ul>

*Table 7 LOs of Cell 1 (Initiating Integration Management)*

<b>“Cell 1: Initiating Integration Management” learning objectives</b>
<b>Note:</b> This cell contains three (3) KUs (i.e., pre-initiating processes, overview of initiating, develop project charter)
<ul style="list-style-type: none"> <li>• Describe the content of a business case</li> <li>• Describe the pre-initiating processes</li> <li>• Describe the processes in the initiating process group</li> <li>• Develop a project charter and assumption log</li> </ul>

*Table 8 LO of Cell 22 (Executing Risk Management)*

<b>“Cell 22: Executing Risk Management” learning objectives</b>
<b>Note:</b> This cell contains only one (1) KUs (i.e., implement risk response)
<ul style="list-style-type: none"> <li>• Explain how risk responses are implemented as part of risk management execution processes</li> </ul>

### — END OF OUR IMPLEMENTATION EXAMPLE —

### **3. Structuring and developing the knowledge units (KUs)**

Course developers should use a matrix approach to create a structured and practical learning experience, aligning course modules with relevant knowledge areas. This systematic organisation ensures a clear learning path, allowing learners to engage with targeted, well-structured content.

In this approach, the knowledge domain represents a broad field of expertise encompassing multiple related topics. Topics are more specific subcategories within these domains, focusing on work processes, activities, or concepts. A well-designed matrix maps course topics (columns) against knowledge domains (rows), providing a logical framework for content delivery, as illustrated in Table 9.

Table 9 Example of a KU matrix

KU Matrix	Topic 1	Topic 2	Topic 3
Knowledge Domain 1	KU 1.1	KU 2.1	KU 3.1
Knowledge Domain 2	KU 1.2	KU 2.2	KU 3.2
Knowledge Domain 3	KU 1.3	KU 2.3	KU 3.3

Each intersection represents a specific KU to ensure a logical and coherent learning path. Course developers must also consider the requirements for each KU, which should be tagged with metadata.

Considerations	
1	<b>Topic area and knowledge domain</b>
	Ensure the KU is categorised within a structured knowledge domain to maintain logical progression.
2	<b>Difficulty level</b>
	Label each KU appropriately (e.g., beginner, intermediate, advanced) to support learners at different proficiency levels.
3	<b>Estimated completion time</b>
	Define the approximate time required to complete the KU, ensuring it is manageable for professional learners.
4	<b>Learning format</b>
	Specify the format of the KU (e.g., video, quiz, exercise, reading material) to provide variety and support diverse learning preferences.

Learning activities may include, but are not limited to, lecture videos, quizzes, ungraded exercises, and reading lecture handouts. If a KU activity exceeds 10 minutes, it should be divided into smaller, bite-sized sections. KU activities must be flexible, allowing learners to pause and resume anytime. Professionals often balance multiple responsibilities, so they may need to step away from a KU due to work or personal commitments.



## Guidelines for developing KU

### 1 Content should be in bite-size

Each KU should be concise and structured to be completed within a short duration (e.g., 10–15 minutes). This enhances learner engagement and retention while fitting into busy professional schedules.

### 2 Modular in structure

KUs should be self-contained and adaptable to different learning paths, ensuring reusability across multiple courses. To enhance accessibility, KUs should support progress tracking with automatic bookmarking, allowing learners to resume seamlessly. They should be accessible across devices for a consistent experience and remain available for future reference, enabling learners to review content as needed. This modular approach promotes flexibility, engagement, and continuity in learning.

### 3 Define the pre-requisites (if any)

Identify any necessary prerequisites for each KU. This ensures learners acquire foundational knowledge before progressing to more complex concepts, preventing knowledge gaps and improving learning efficiency.



## HOW WE IMPLEMENT IN OUR ALS PD COURSE

We designed the KU matrix to align with the PM's process groups and knowledge areas (Figure 7), ensuring a structured and comprehensive approach to essential PM concepts. This framework maintains a logical progression throughout the curriculum, with each cell representing the intersection of a process group and a knowledge area, potentially containing multiple KUs (Figure 8).

KA/PG	(A) Initiating	(B) Planning	(C) Executing	(D) Monitoring & Controlling	(E) Closing
(1) Integration	02-02 Pre-initiating processes 02-03 Overview of initiating 02-04 Develop project charter	1 03A-02a Key PM plan components and change management plan 03A-02b Stakeholders and configuration management 03A-02c Change management versus configuration management 03A-02d Performance measurement baselines 03A-02e Performance elements in the plan	2 04A-02a Deliverables and work performance data 04A-02b Issuing log and change request 04A-02d Manage project knowledge	3 05A-02a Monitor and control project work 05A-02b Control project work 05A-02c Earned value management (EVM) 05A-02d Summary of EVM terms and formulas 05A-02e Summary of EVMS 05A-03 Perform integrated change control	4 06-02a Common ways to close or terminate projects 06-02b Close-out meeting 06-02c Example of just-in-time project 06-02d Close-out meeting and warranty period 06-02d Lessons learned
(2) Scope			6 03A-03a Plan scope management 03A-03b Define scope 03A-03c Verify scope and review of work breakdown structure (WBS) 03A-03e Developing a good WBS	5 05A-04 Validate scope 05A-05 Control scope	7
(3) Schedule			8 03B-02a Develop schedule management plan 03B-02b Define activities 03B-02c Sequence activities 03B-02d Define duration 03B-02f Estimate activity duration 03B-02g Define critical path 03B-02h Critical path method 03B-02i Develop a Gantt chart 03B-02j Critical chain scheduling	9 05A-06 Control schedule	
(4) Cost			10 03B-03a Plan cost management 03B-03b Estimate costs 03B-03c Develop budget, baseline and budget components 03B-03d Example of construction project budget 03B-03e Develop a budget expenditure and funding requirements	11 05A-07 Control costs	
(5) Quality		12 03C-02a Principles of quality management 03C-02b Quality metrics	13 04A-03a Benefits of manage quality process, tools and techniques 04A-03b Quality report	14 05B-02a Overview of quality control tools 05B-02b Quality control tools (Cause and effect diagram, check sheet, control chart, histogram, Pareto chart, scatter diagram, and stratification)	
(6) Resource		15 03C-03a Plan resource management 03C-03b Resource histogram 03C-03d Staff management plan 03C-03e Estimating activity resources	16 04B-02 Acquiring resources 04B-02b Team development 04B-02c Team building 04B-02d Team building activities 04B-02f MTB and TRACOM Social style model 04B-02g Team building recognition systems 04B-02l Cultural diversity 04B-02m Conflict resolution 04B-02n Conflict management in construction projects 04B-02o Conflict resolution process and importance of EQ 04B-02p Leader versus manager 04B-02q Leader versus team 04B-02r Extrinsic and intrinsic motivation 04B-02s How extrinsic motivation influences behavior 04B-02t How motivation influence projects	17 05B-03 Control resources	
(7) Communications		18 03C-04a Communication management plan 03C-04b Project communication technologies 03C-04c Project stakeholders	19 04B-05a Manage communications 04B-05b Types of communication 04B-05c Identify communication needs 04B-05d Impact of team size on project communication	20 05B-04 Monitor communications	
(8) Risk		21 03D-02a Plan risk management 03D-02b Risk management plan template 03D-02c Identify risks 03D-02d Quantify risks 03D-02e Example of risk register	22 04A-04 Implement risk responses	23 05B-05 Monitor risks	
(9) Procurement		24 03D-03a Procurement management plan 03D-03b Contract types, common standard form of contracts and project types 03D-03c Contract types, common standard form of contracts and project types 03D-03d Make-or-buy decision 03D-03e Bid documents and statement of work 03D-03f Procurement strategy and supplier evaluation matrix 03D-03g Procurement-related risk management	25 04A-05a Approaching and selecting sellers and suppliers 04A-05b Standard agreements in construction industry	26 05B-06a Examples of procurement activities 05B-06b Quality of rental 05B-06c Financial management and effective change management	
(10) Stakeholder	02-05 Stakeholder identification 02-06 Kick-off meeting	27 03C-05a Stakeholder engagement plan and power/interest grid 03C-05b Stakeholder engagement categories 03C-05c Example of stakeholder engagement plan	28 04B-06a Manage stakeholder engagement 04B-06b Construction project example	29 05B-07 Monitor stakeholder engagement	30

Figure 7 Developed the KU matrix based on process group and knowledge areas

16	
04B-02 Acquiring resources	
04B-03a Developing project team	
04B-03b Tuckman model of team development	
04B-03c High-performing teams and team building activities	
04B-03d MBTI and TRACOM Social Style model	
04B-03e Reward and recognition systems	
04B-03f Cultural diversity	
04B-04a Conflict management	
04B-04b Example of conflict management in construction projects	
04B-04c Conflict resolution process and importance of EQ	
04B-04d Managing teams	
04B-04e Leader versus manager	
04B-04f Leadership styles	
04B-04g Extrinsic and intrinsic motivation	
04B-04h Motivation theories	
04B-04i How motivation influence projects	

Figure 8 Example of Cell 16 containing multiple KUs (i.e., one video is one KU)

Our course structure follows the PM matrix (Figure 7), breaking learning into smaller, manageable KUs. Each cell may contain multiple KUs, and to enhance accessibility, we develop bite-sized content with videos no longer than 10 minutes (see Table 10 for an example). The organisation of KUs can vary depending on course design. For instance, a course designer may group KUs by process groups. In one case, we grouped the KUs from Cell 1 and Cell 27 under the “Initiating Process Group”, as illustrated in Figure 9.

Table 10 Sample list of our lecture videos categorised by modules and cells

mod. no.	cell no.	ref. no.	description	duration
2	1	02-02	Pre-initiating processes	0:06:19
2	1	02-03	Overview of initiating	0:01:49
2	1	02-04	Develop project charter	0:09:32
2	27	02-05	Stakeholder identification	0:03:39
2	27	02-06	Kick-off meeting	0:02:00

The screenshot shows a Canvas module page for 'WEEK 2 | MODULE 2 | Initiating Process Group'. At the top right, there is a button labeled 'Complete all items' with a green checkmark icon. Below the title, there is a section titled 'TASKS' with a clipboard icon. Underneath, there are five listed items, each with a green checkmark and a 'View' link:

- Module 02 Lecture Videos**
- Module 02 Handout**
- Module 02 Practice Quiz**  
3 Feb | 0 pts | Submit
- Module 02 Discussion: Project Charter**
- Module 02 Supplementary Discussion: Stakeholder Identification (Sydney Airport)**

Figure 9 Grouping of multiple KUs into one module under Initiating Process Group in Canvas

For example, the Module 02 Canvas page includes key details such as the estimated time to complete the module, learning objectives, a list of video lectures (covering Cell 1 and 27 as part of the initiating process group), video durations, and the accompanying adaptive quiz (see Figure 10).

# MODULE 02

## INITIATING PROCESS GROUP

 Estimated completion time: 30 min

In this module, you will learn about pre-initiation processes and how to initiate a project. Most of the materials are based on [Process Group: A Practice Guide \(PGPG\)](#) by Project Management Institute (PMI). You can download a copy of PGPG [here](#).

[Link to Module 02](#)

### Learning Outcomes

At the end of the module, learners should be able to:

1. Describe the content of a business case
2. Describe the pre-initiating processes
3. Describe the processes in the initiating process group
4. Develop a project charter and assumption log
5. Perform stakeholder identification during project initiation
6. Hold a project kick-off meeting

### Video Lectures

02-01 Introduction (01:10)



02-02 Pre-initiating processes (06:19)



Figure 10 Sample Canvas page design with the recommended metadata

— END OF OUR IMPLEMENTATION EXAMPLE —

#### 4. Developing the recommender engine, algorithms and feedback loops

The recommender engine is the core of KUR and generates personalised learning pathways based on learner data. Developing an effective recommender system requires selecting the right algorithms, processing learner data efficiently, and continuously refining recommendations to enhance learning outcomes. A well-designed recommender engine uses AI-driven techniques to generate personalised learning pathways.

*Table 11 List of standard recommendation algorithms*

Algorithm	Description
Content-Based Filtering	Suggests learning units like those the learner has previously engaged with by analysing metadata, keywords, and topic similarity.
Collaborative Filtering	Identifies patterns among similar learners and recommends content based on what others with similar profiles have found useful.
Hybrid Recommender Systems	Combines content-based and collaborative filtering to improve accuracy and diversity in recommendations.
Reinforcement Learning	Adjusts recommendations dynamically based on learner interactions, adapting as users engage with the system.
Large Language Models (LLMs)	Utilises natural language processing to better understand user queries and refine learning pathways based on learner input.

The selected algorithms should align with the learning system's objectives, ensuring efficiency and accuracy in content recommendations. The system generates a structured learning pathway once the algorithm processes the learner's profile and preferences. The [recommended readings](#) provide more information.



## Guidelines on generating and refining learning pathways

### 1 Logical sequencing of knowledge units

The learning pathway should guide learners through a structured progression, ensuring foundational topics are covered before advancing to more complex concepts. Clear prerequisite relationships help prevent knowledge gaps and create a smooth transition between different difficulty levels.

### 2 Dynamic adaptation based on learner progress

The system should continuously assess learner performance through quizzes, assessments, and engagement metrics. If a learner excels, more advanced content can be introduced, whereas additional resources such as explanations, practice exercises, or alternative learning formats should be recommended if they struggle.

### 3 Estimated completion times for effective planning

Each KU should include an estimated completion time, allowing learners to manage their study schedules efficiently. This feature helps them allocate time appropriately, set realistic goals, and prevent cognitive overload by pacing their learning experience effectively.

Additionally, a high-performing recommender engine should evolve. By incorporating machine learning models and real-time learner feedback, the system can:



### **Recommender engine feedback loop**

- 1 Identify patterns in learner engagement and refine recommendations accordingly**
- 2 Adjust algorithms based on new data, ensuring content remains relevant and effective**
- 3 Enhance interpretability, providing learners with explanations for why certain content is recommended**
- 4 Estimated completion times for effective planning**

Well-crafted LLM prompts ensure that recommendations are accurate, relevant, and tailored to the learner's background, preferences, and time constraints. These prompts also guide the AI system in delivering precise and optimised learning paths. A sample LLM prompt template is available in [Annex B](#).



### **Guidelines on developing an effective LLM prompt for KUR**

#### **1 Define role and scope**

Clearly specify the AI's role (e.g., "You are a learning advisor") and define the course structure, including course modules, knowledge areas, and their rankings.

#### **2 Capturing learner profile and prior knowledge**

Specify that the AI must tailor recommendations based on individual learner attributes. Learner inputs include job role, industry experience, qualifications, learning preference, pre-test or baseline scores, time constraints, and availability.

### 3 Structuring learning paths based on KUs

Specify that the AI must select optimal KUs based on learner needs and time constraints, and the KUs are categorised based on topic, difficulty level, and estimated learning time.

### 4 Include time constraints and scheduling flexibility

Learners may have limited time for learning, requiring an optimised schedule. AI should prioritise high-impact KUs within the available time and help balance workload to prevent cognitive overload.

### 5 Output formatting and selection criteria

Ensure the AI returns the learning path in a structured format. It should list the sequence of recommended KUs, provide a rationale for selection, and maintain clarity and readability.



## HOW WE IMPLEMENT IN OUR ALS PD COURSE

Our KUR development utilises LLMs to generate personalised learning pathways for professionals, as illustrated in Figure 11. The system dynamically generates up to ten (10) alternative learning paths tailored to the learner's profile, which includes their demographics, ranking of process groups and knowledge areas, time constraints (e.g., in our course, we limit it to a maximum of three hours), and prior knowledge based on the pre-course quiz that learners took at the start of the course.

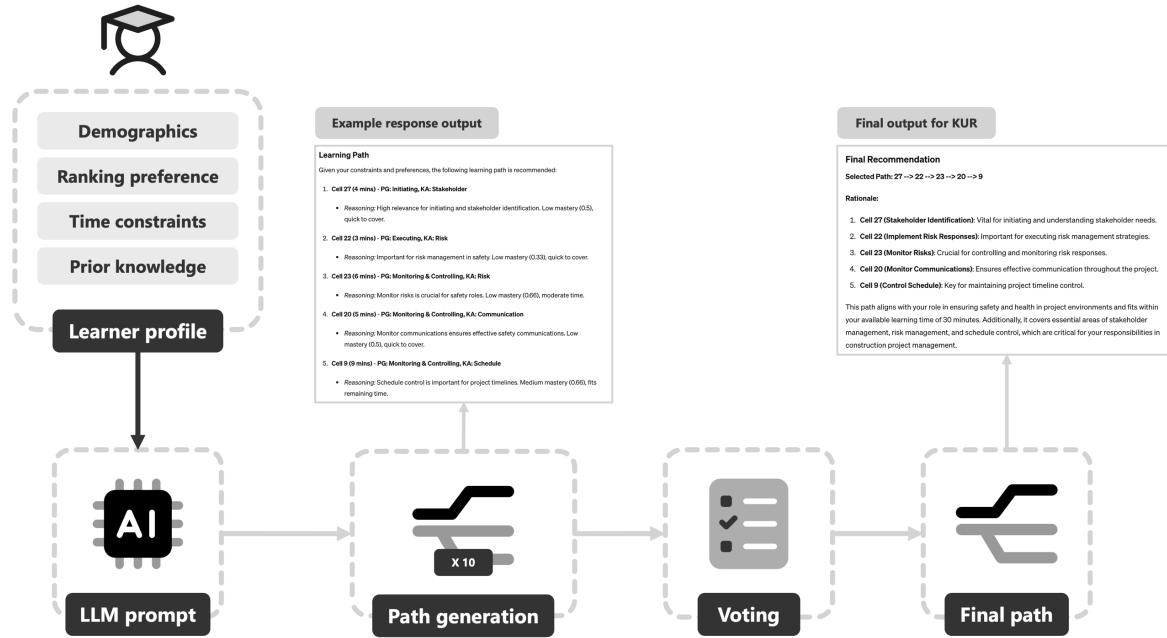


Figure 11 Our KUR workflow using LLM to generate learning paths

The system uses a voting ensemble to evaluate multiple generated learning paths and select the most optimal one based on KU similarity. This approach leverages a voting algorithm to facilitate decision-making under specific conditions and constraints. The assigned role in the prompt is to differentiate the output paths, which are then combined to form the final learning path based on selection criteria. The resulting path consists of structured modules with estimated completion times and built-in progress-tracking mechanisms.

Table 12 Our LLM prompt for generating personalised learning paths

</>

### **LLM prompt: Generating personalised learning path**

You are an experience project manager trainer and course developer for Project Management course. This course is divided into five (5) process group (PG): Initiating, Planning, Executing, Monitoring and Controlling, and Closing, and each containing ten (10) knowledge areas (KA): Integration, Scope, Schedule, Cost, Quality, Resources, Communication, Risk, Procurement, and Stakeholders. Learners can rank their preferences for these modules and knowledge areas from 1, 2, 3, 4, 5 and 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 respectively, prioritising based on career needs and prior knowledge.

Here are the details of each cell based on PG and KA:

Cell 1 (PG = Initiating, KA = Integration) – Develop project charter

... [details of Cells 2 to 29]

Cell 30 (PG = Monitoring and Controlling, KA = Stakeholder) – Monitor stakeholder engagement

I have a time constraint and can learn the recommended path within timeframe of 180 minutes. Strictly adhere to the time constraint and do not exceed 180 minutes. If the time exceeds the time constraint, the recommendation will be rejected. Different cells need learning timeframe. Cell-mins pair: {1: 29, ..., 30: 8}. For example, if I were to study Cell 1, I would have to spend 29 minutes.

The learner is a Workplace Safety and Health Officer with 11 to 16 years of experience in construction industry. Their preferred learning style includes lecture videos and ungraded exercises. Their pre-test scores indicate strengths in executing risk management and weaknesses in planning process group.

Please recommend a learning path according to the learner's background and prior knowledge. Return only the path. Do not list intermediate paths. You must provide the path and strictly in this format: [1, 2, nth]. Do provide the selection criteria and summarise the rationale behind the recommendation of this learning path.

Table 13 Output from the LLM prompt

</>      Output from LLM: Sample learning path
<p>Output:</p> <p>[2, 19, 22, 26, 25, 20, 5, 28, 10, 29, 1, 24]  [1, 2, 3, 18, 19, 24, 25, 27, 28, 29]  [2, 24, 1, 5, 25, 27, 18, 28, 19, 29, 20, 30]  [1, 2, 18, 24, 25, 27, 28, 29]  [3, 16, 21, 25, 1]  [24, 19, 2, 18, 27, 3]  [2, 18, 19, 25, 20, 26, 27]  [2, 18, 19, 24, 25, 27, 28]  [1, 2, 5, 19, 24, 25, 29]  [2, 1, 5, 19, 18, 27, 24, 25]</p> <p>Final Recommendation:</p> <p>Selected path: 27 -&gt; 22 -&gt; 23 -&gt; 20 -&gt; 9</p> <p>Rationale:</p> <ol style="list-style-type: none"> <li>1. Cell 27 (Stakeholder identification): Vital for initiating and understanding stakeholder needs.</li> <li>2. Cell 22 (Implement risk responses): Important for executing risk management strategies.</li> <li>3. Cell 23 (Monitor risks): Crucial for controlling and monitoring risk responses.</li> <li>4. Cell 20 (Monitor communications): Ensures effective communication throughout the project.</li> <li>5. Cell 9 (Control schedule): Key for maintaining project timeline control.</li> </ol> <p>This path aligns with your learner's role in ensuring safety and health in project environments and fits within your available learning time. Additionally, it covers the essential areas of stakeholder management, risk management and schedule control, which are critical for your learner's responsibilities in construction project management.</p>

— END OF OUR IMPLEMENTATION EXAMPLE —

### 3.3 Best Practices and Considerations for KUR



#### Best practices for KUR

##### 1 Conduct pilot testing with a small group

This process involves implementing the KUR in a controlled test environment, where selected learners can interact with the system and provide valuable feedback. By analysing user interactions, performance trends, and engagement levels, developers can identify potential issues and areas for improvement. The insights gathered from this phase should be used to refine the recommendation engine, enhance content relevance, and ensure the system adapts optimally to diverse learner needs before actual implementation.

##### 2 Ensure transparency in the recommendation logic

Clearly explain why specific knowledge units are suggested and how they align with the learner's progress, preferences, and goals. Providing learners with detailed reasoning behind recommendations fosters trust and encourages active engagement. Additionally, offering a structured view of their personalised learning path, progress tracking, and the ability to adjust their recommendations empowers learners to take ownership of their educational journey and enhances motivation.

##### 3 Design for scalability and flexibility

Ensure that the system can accommodate increasing learners, evolving content, and multiple learning pathways without compromising performance. A well-structured KUR should support modular course structures, allowing seamless integration of new knowledge units while maintaining consistency across different learning experiences. The system should also adapt to various industries and professional development needs, making it versatile for educational and corporate settings.

4

## Continuously monitor and improve recommendations

Use data-driven insights to refine the system's accuracy and effectiveness. Leverage learner feedback, engagement metrics, and AI-driven analytics to identify patterns in user behaviour and adjust recommendations accordingly. Regular updates to the recommendation engine should incorporate emerging learning trends, improve content relevance, and enhance the user experience.



## Ethical considerations

**Ethical concerns must be addressed when developing AI-driven learning pathways to ensure fairness, inclusivity, and data privacy.**

1

### Bias mitigation in recommendations

- AI-generated recommendations must be free from biases based on gender, age, or background.
- The system should implement fairness checks to ensure diverse and balanced recommendations.
- For example, if an AI model repeatedly recommends leadership courses to male learners but not female learners, it should be reviewed for bias.

2

### Learner privacy and data protection

- Implement strict data anonymisation practices, ensuring sensitive information is not exposed.
- Learner profiles should not store personal identifiers beyond what is necessary for recommendation accuracy.

## 4 Adaptive Quiz (AQ)

### 4.1 Overview and Features of AQ

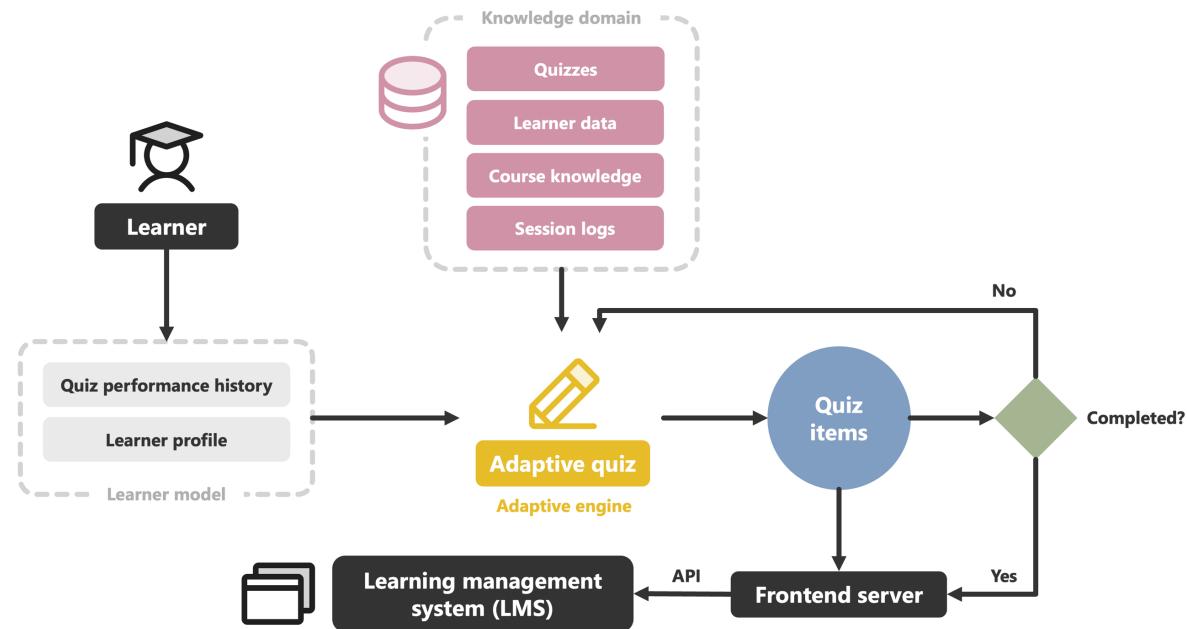


Figure 12 Example of AQ system workflow integrated with LMS

Adaptive Quiz (AQ) is an intelligent, data-driven assessment tool that dynamically adjusts the difficulty and selection of questions based on a learner's real-time responses. Unlike traditional static quizzes that follow a predefined structure, AQ continuously adapts to the learner's skill level, ensuring a personalised and optimised testing experience.



#### Key features of our AQ workflow

##### 1 Real-time question adaptation

The quiz modifies question difficulty based on the learner's answers, ensuring that learners are neither overwhelmed nor under-stimulated. It helps to accurately determine knowledge levels with fewer questions than static quizzes.

##### 2 AI-driven question selection

It uses data-driven algorithms and AI to predict the next suitable question and ensures optimal sequencing of questions for a precise assessment.

### 3 Continuous progress tracking and analytics

It provides detailed performance reports and historical tracking, highlights knowledge gaps, and suggests additional resources. It also helps generate insights for educators to refine curriculum.

## 4.2 Implementation Guidelines for AQ

To implement AQ effectively, several key components and methodologies must be established. In this section, we illustrate our development approach. While our methodology has proven to be the most suitable within our context, it is not the only viable approach. We encourage you to modify or adapt these methods to best align with the unique requirements of your PD course.

### 1. Database schema and system setup

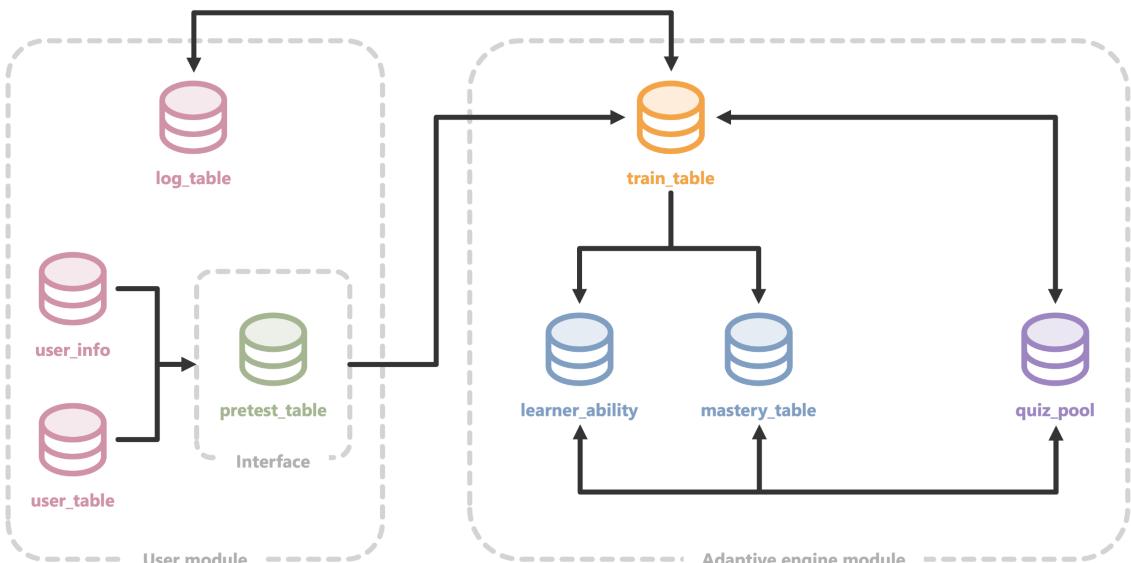


Figure 13 Example of the database schema for AQ

A well-structured database schema is crucial for managing user credentials, quiz content, learner performance, and progression tracking. It uses historical performance records to enhance recommendations, making it an essential component of KUR and PF systems.

Table 14 Suggested parameters for the database schema for AQ

Parameters	Description
<b>User identifiers</b>	Unique user IDs that track quiz history and mastery progress.
<b>Quiz metadata</b>	Storage of quiz questions, multiple-choice options, correct answers, explanations, and hierarchical categories.
<b>Learning ability</b>	Real-time knowledge level estimations using Item Response Theory (IRT) models.
<b>Mastery tracking</b>	Dynamic updates of user proficiency across topics based on responses.
<b>Pre-test performance</b>	Initial knowledge levels are recorded through baseline assessments.
<b>Training data</b>	Logs correct and incorrect answers in binary form (0 or 1) to dynamically update mastery tracking and learning ability.
<b>User activity logs</b>	Captures quiz interactions, timestamps, response attempts, and selected answers.



## Considerations

### 1 Setting up an administrator site for system control and monitoring

Course developers should collaborate with educational technologists, research engineers, software developers, and LMS administrators to deploy an administration site to monitor learner progress, control system access, and update quiz content.

## 2. Development of quiz bank

Each quiz question must be tagged with metadata, allowing the system to select appropriate questions dynamically. Every question should align with a specific learning objective to ensure measurable learning outcomes. To ensure adequate questions for each KU, we follow this guideline for developing our quiz bank: **a five-minute video lecture should include at least three (3) quiz items.**

This approach is necessary because a single module may cover multiple KUs, and the quiz questions should be proportionate to the video's length to assess understanding accurately. Course developers are encouraged to use LLM to generate diverse question formats, including multiple-choice and scenario-based questions while ensuring that questions remain accurate and relevant through expert review. Examples of LLM prompts used to create question items are available in [Annex B](#).

 Guidelines on generating and refining learning pathways	
<b>1</b>	<b>Mapping questions to specific KUs</b>
	Each question is mapped to a specific knowledge unit within the course structure for structured learning progression.
<b>2</b>	<b>Categorising questions by difficulty</b>
	Questions are categorised into difficulty levels (i.e., beginner, intermediate, advanced) to match learner proficiency. Discrimination levels indicate how well a question differentiates between learners of different skill levels, and these values are updated dynamically based on learner responses.
<b>3</b>	<b>Providing correct answers and explanations</b>
	Every question must include correct answers and explanations to provide meaningful learning feedback.
<b>4</b>	<b>Support for multiple question formats</b>
	Supports multiple-choice questions (MCQs), scenario-based questions, case studies, and short-answer questions.



## HOW WE IMPLEMENT IN OUR ALS PD COURSE

There are several ways to develop a quiz bank. Our approach involves extracting questions from multiple sources, including textbooks and academic references, ensuring a diverse and well-rounded question pool. We then manually tag these questions to the corresponding KUs, aligning them with the course structure to maintain coherence and relevance.

Our quiz bank stores each question with four answer options, the correct answer key, and the rationale behind the answer, as illustrated in Figure 14. Providing the rationale ensures learners receive immediate feedback, helps them understand the reasoning behind correct responses, and reinforces their learning. This structured approach to quiz bank development enhances the effectiveness of assessments, supporting a more personalised and adaptive learning experience.

mod	cell	questions	optA	optB	optC	optD	answer	rationale
2	1	Which of the following processes is typically not part of the pre-initiating phase in project management?	Defining the project's objectives and success criteria	Involve stakeholders to create a shared understanding of the success criteria	Developing the project charter	Establishing the project team and assigning roles and responsibilities	C	The project charter is usually developed during the initiating phase. It formally authorises the project and gives the project manager the authority to apply organisational resources to project activities.
3A	6	Marty, the project manager, is working with his team members to create the WBS. He shows the team how to divide the project scope into the WBS components, but the team does not understand how far down the breakdown should occur. What is the lowest-level item in a WBS?	A work package	A deliverable	An activity	A leaf object	A	The smallest item in the WBS is called the work package. A "deliverable" may be accurate, but a "work package" is a more precise answer. An "activity" is incorrect because activities are in the activity list, and a "leaf object" is an invalid WBS term.
3A	6	You will use the scope management plan to define the project scope statement. You will also use this plan to build the scope baseline. Which two items are parts of the scope baseline for the project?	Time and cost baselines	The project scope management plan and project charter	The project scope management plan and the WBS	The WBS and WBS dictionary	D	The WBS and WBS dictionary are two of the three components of the scope baseline. The approved detailed project scope statement is the third portion of the scope baseline. The other options are all incorrect because they do not accurately define the scope baseline.
4A	3	You report on project elements such as schedule status, deliverables completion, lessons learnt, and resource utilisation. Which of the following outputs of the Direct and Manage Project Work does this describe?	Project management plan updates	Project documents updates	Preventive action	Work performance data	D	Work performance data includes elements such as schedule status, the status of deliverables completion, lessons learned, and resource utilisation.

Figure 14 Snippet from our quiz bank

To ensure adequate question coverage for each KU, we follow a simple rule: a five-minute video lecture should include at least three quiz items (Table 15). This ensures that learners engage with the content actively and reinforce their understanding through assessment. However, some KUs may have fewer than the required number of questions. In such cases, we leverage LLMs to generate additional quiz items, maintaining consistency in question quality and alignment with learning objectives.

Table 15 Our quiz bank tracker to determine how many questions are required

cell	description	duration	req	count
1	Initiating integration management	0:17:40	12	14
2	Planning integration management	0:22:01	15	17
3	Executing integration management	0:21:57	14	16
4	Monitoring and controlling integration management	0:36:29	23	25
5	Closing integration management	0:18:09	12	14

To generate these questions, we upload lecture transcripts and handouts to the LLM and prompt it to create relevant quiz items. This approach helps fill gaps in the quiz bank and ensures that the generated questions are contextually accurate and aligned with the course material.

Table 16 Example of our LLM prompt to generate items for quiz bank

#### </> LLM prompt: Generating quiz bank

From the uploaded transcript (05b-03), developed five (5) high-order thinking multiple choice questions. Please craft the questions for adult learners and make it as a construction context and can refer to project management references.

Make each question a case study where the learners are project managers in construction context where learners can apply concepts. Each question should have 4 options. Highlight the correct answer.

Provide an explanation for the correct and incorrect options. Write in GB English. Make it questions difficult. For the explanation, please write in one paragraph for each question. Start with the correct option and state that "the other options are wrong because..."

— END OF OUR IMPLEMENTATION EXAMPLE —

### 3. Question selection algorithm

AQ relies on advanced algorithms to adjust the difficulty dynamically, select optimal questions, and accurately assess learner proficiency. Here are some of the most used adaptive algorithms:

Table 17 Common algorithms to select the quiz questions in AQ

Algorithm	Advantages	Disadvantages
<b>Item Response Theory (IRT)</b> It is a statistical model used in many standardised tests. It estimates the <i>learner's ability</i> and <i>item difficulty</i> .	<ul style="list-style-type: none"> <li>Efficient and widely used in high-stakes exams</li> <li>Quickly pinpoints the learner's knowledge level</li> <li>Reduces test length without sacrificing accuracy</li> </ul>	<ul style="list-style-type: none"> <li>Requires a pre-calibrated question bank with difficulty parameters</li> <li>Cannot handle multi-dimensional learning paths</li> </ul>
<b>Bayesian Knowledge Tracing (BKT)</b> It is a probabilistic model used to track learner knowledge over time. It predicts the probability that a learner has <i>mastered a skill</i> based on their responses.	<ul style="list-style-type: none"> <li>Models learning over time</li> <li>Can track multiple skills</li> <li>Helps predict when to introduce new concepts</li> </ul>	<ul style="list-style-type: none"> <li>Less effective for assessing non-binary knowledge (e.g., complex problem-solving)</li> <li>Requires well-structured knowledge models</li> </ul>
<b>Reinforcement Learning-Based Adaptive Quizzing</b> Reinforcement Learning (RL) adapts quizzes based on reward signals, treating the quiz process as a learning game.	<ul style="list-style-type: none"> <li>Works without pre-defined difficulty levels</li> <li>Continuously optimises question selection</li> <li>Ideal for game-based learning environments</li> </ul>	<ul style="list-style-type: none"> <li>Requires large datasets to train effectively</li> <li>Computationally expensive</li> </ul>

<p><b>Knowledge Graph-Based Adaptive Quizzing</b></p> <p>It is a network of concepts and their relationships, helps structure learning paths by ensuring prerequisite knowledge is mastered before introducing new topics.</p>	<ul style="list-style-type: none"> <li>• Ensures logical progression of learning</li> <li>• Prevents knowledge gaps</li> <li>• Works well for multi-disciplinary learning</li> </ul>	<ul style="list-style-type: none"> <li>• Requires a well-defined knowledge graph</li> <li>• Harder to implement for open-ended subjects</li> </ul>
--	--	--

Item Response Theory (IRT) is the most common method used in AQ systems. It provides a robust framework for modelling the relationship between an individual's ability and performance on quiz items (Huda et al., 2024). One of the most well-known examples is Computerised Adaptive Testing (CAT), which follows a general process of initial ability estimation, selecting the questions that match the current ability level and updating the parameters based on the response (Liu et al., 2024).

The IRT model presents new question parameters based on learner performance. If a question is frequently answered correctly, it may be more difficult for future users. If a question is often answered incorrectly, the system may provide hints to recommend additional content or adjust the difficulty level for future learners.



## HOW WE IMPLEMENT IN OUR ALS PD COURSE

Our selection algorithm combines Item Response Theory (IRT) with the Upper Confidence Bound (UCB), a multi-armed bandit approach. This hybrid method leverages psychometric modelling and reinforcement learning for adaptive learning. It selects questions based on their fit for the learner and the uncertainty in our estimates, balancing familiar topics with new challenges.

Learners begin with a pre-assessment to identify strengths and weaknesses. As they progress, the system updates their ability levels and selects questions accordingly. If a learner struggles, it provides well-matched questions while updating their ability level to decide whether to reinforce familiar concepts or introduce new challenging topics. Therefore, this combination could work by maintaining ability estimation and dealing with real-time adaptation. The [recommended reading](#) provides more details on the different methods.

### Question 2

You are managing a construction project with a budget of \$800,000. The project involves two construction teams working for six months, totalling 10,000 hours of labour. According to your project schedule, 38% of the work should be completed by now. However, you've noted that 40% of the work is complete, but 50% of the budget has already been spent. What does this indicate about your project's status?

- Option A:** The project is ahead of schedule and under budget.
- Option B:** The project is ahead of schedule but over budget.
- Option C:** The project is behind schedule but under budget.
- Option D:** The project is on schedule but over budget.

### Result: Correct

The project is ahead of schedule (40% completed vs. 38% planned) but over budget (50% spent vs. 40% work done). Thus, the correct answer is 'The project is ahead of schedule but over budget.' The other options do not correctly describe both the schedule and budget status.

[Next](#)

Figure 15 User interface (UI) of our AQ

Our AQ system allows educators and learners to adjust the exploration parameters, time duration, total number of questions, and topic(s) they want to practice in the quiz based on their preferences, as illustrated in Figure 16.

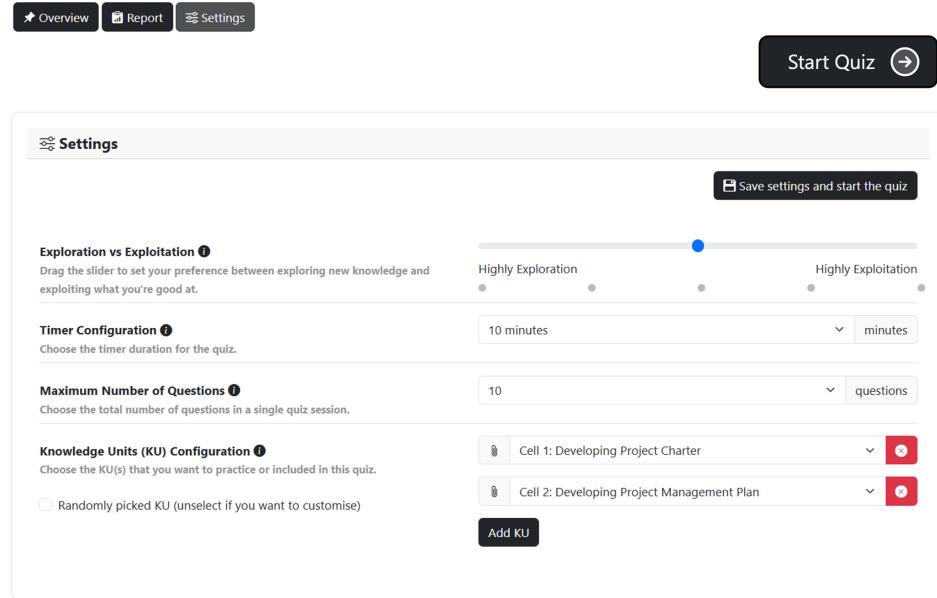


Figure 16 Various setting options in our AQ portal for the learners to take control of their learning

— END OF OUR IMPLEMENTATION EXAMPLE —

### 4.3 Best Practices and Considerations for AQ



#### Best practices for KUR

##### 1 Ensure balanced question difficulty

Structure the quiz to progressively challenge learners without causing frustration. The system should start with easier questions and gradually introduce more complex ones based on learner performance. This adaptive approach helps maintain motivation and ensures that learners are neither disengaged by “too easy” questions nor overwhelmed by overly difficult ones.

##### 2 Minimise redundant questions

Implement an intelligent question rotation system (i.e., session tracking and learner history) to prevent learners from repeatedly encountering the same questions. The system should track attempted questions and responses, ensuring learners receive fresh challenges while reinforcing key concepts through spaced repetition.

##### 3 Optimise feedback for engagement

Deliver meaningful and immediate feedback after each question, including explanations for incorrect answers and links to relevant learning resources. Adaptive feedback should help learners identify knowledge gaps and offer tailored recommendations for improvement, enhancing the learning experience (see [Personalised Feedback](#)).

**4 Regularly update the quiz bank**

Expand and refine the question pool to ensure continuous improvement. Course developers should periodically add new questions, adjust difficulty levels based on performance analytics, and review questions for clarity, relevance, and accuracy. AI and LLM can help generate high-quality questions across knowledge domains.

**5 Ensure adequate question coverage for each KU**

Each quiz should have enough questions per KU to provide comprehensive assessment coverage. A general rule of thumb is to include at least three quiz questions for every five-minute video lecture to reinforce key learning objectives effectively.



## Limitations and other considerations

These are some common issues that course developers may encounter when adopting the AQ.

### 1 Real-time IRT parameters

- The system dynamically updates estimates in real time, requiring session or temporary storage on the server.
- Item parameters are updated every quiz session, rather than using fixed values.
- May introduce some bias but significantly enhances personalisation and adaptive learning.

### 2 Repetitive questions

- Some users may initially receive similar or redundant questions but as the system collects more training data, it improves and reduces repetition.
- Users should be informed beforehand about potential repetition in early stages.
- Technical teams should store session history (e.g., cookies) to track attempted questions.

### 3 Exhausted questions

- In rare cases, learners may master all topics, leading to no new questions. To prevent this, course developers and educators should:
  - Expand the quiz bank with more diverse and higher-order thinking questions.
  - Use strategic repetition, spaced reinforcement, and alternative question formats.
- Ensures continuous learning opportunities even for advanced learners.

## 5 Personalised Feedback (PF)

### 5.1 Overview and Features of PF

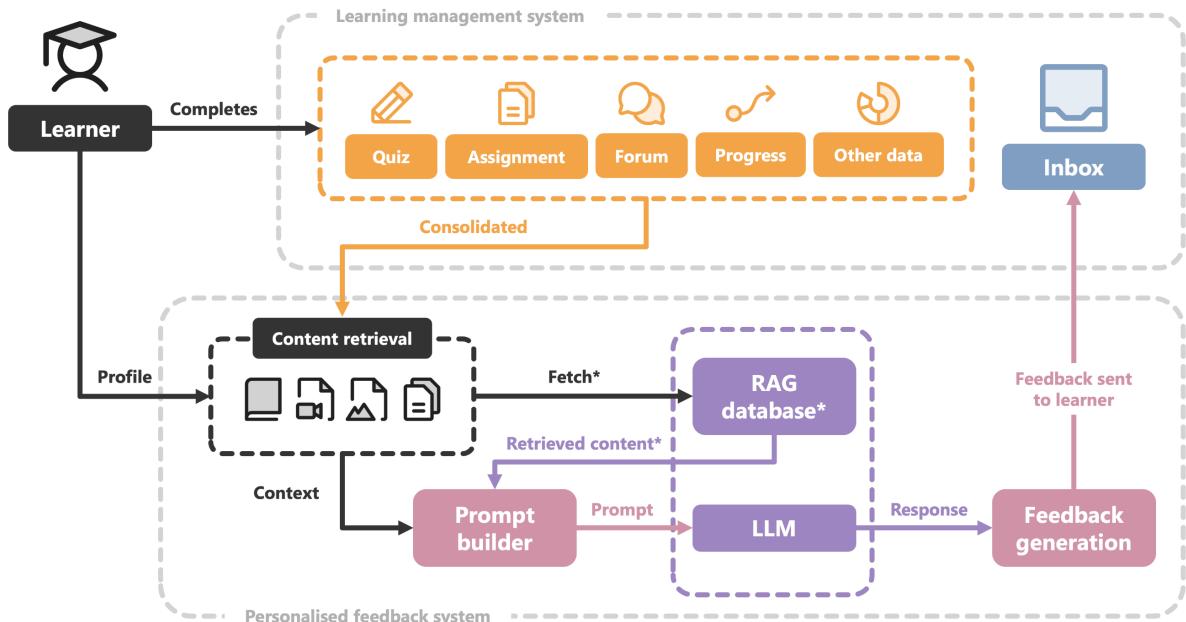


Figure 17 Example of PF workflow integrated with LMS (\*optional components)

Personalised Feedback (PF) is customised, learner-specific feedback based on individual responses, performance, and progress in a learning or assessment system. Unlike generic feedback, PF combines detailed analytics from multiple data sources to address each learner's strengths, weaknesses, and areas for improvement, making learning more effective and engaging. In addition, PF is not just about crafting effective prompts. It is an end-to-end, automated system that transforms raw learner data into tailored, actionable insights.

Training organisations can use PF to support continuous improvement in professional skills, whether in academic settings, industry training, or specialised sectors such as construction. We employ a structured workflow that automates targeted, adaptive, and engaging responses based on learners' progress and needs to deliver effective and meaningful personalised feedback at scale. This workflow consists of several key components:



## Key features of our AQ workflow

### 1 Data collection

The system automatically retrieves data from the Learning Management System (LMS) and other integrated sources. This could include learner interactions, such as quiz responses, time spent on tasks, and common mistakes, to identify strengths and areas for improvement.

### 2 Data processing and analysis

This collected data is processed and summarised into key performance indicators (KPIs) such as submission timeliness, discussion engagement, and progress against course milestones. These KPIs provide the backbone for generating context-rich feedback.

### 3 Contextual prompt generation

The processed data is aggregated into a unified narrative that forms a comprehensive prompt. This prompt could cover multiple areas. For example:

- Assignment Performance – Summaries of submission statuses, scores, and deadlines.
- Engagement Metrics – Insights into discussion forum participation and page view statistics.
- Module Progress – A breakdown of completed versus pending course modules.
- Learner Profile – Demographic and background information that contextualises the feedback.

### 4 Feedback generation and delivery

The structured prompt is submitted to an LLM to generate adaptive, natural language feedback. The resulting feedback is then automatically delivered to learners through the LMS messaging system or a preferred communication channel, ensuring timely and actionable insights.

Large Language Models (LLMs) improve the effectiveness, efficiency, and engagement of the learning experience through their advanced natural language understanding, contextual reasoning, and adaptability capabilities. These models provide real-time, context-aware, and adaptive feedback, allowing learners to receive tailored explanations, clarify misconceptions, and progress at their own pace with greater confidence and understanding.



## Considerations for using LLM for PF

### 1 Context-aware and intelligent explanations

Unlike rule-based systems, LLMs can interpret the learner's response in depth and provide detailed explanations instead of stating right or wrong. It can also provide alternative ways to approach the same problem, and provide personalised phasing based on the learners' proficiency level.

### 2 Scalability and efficiency

LLM can automate feedback generation which reduces manual effort from the course designers and educators. It can provide instant, real-time responses for multiple learners at one go. The system is highly scalable and can be adapted across different subjects and domains.

## 5.2 Implementation Guidelines for PF

This section illustrates our development approach, which integrates LLM into our PF. While the exact technical details will vary depending on your organisation's LMS and preferred technologies, the following guidelines illustrate an approach that training organisations can adopt. The process involves retrieving data from your LMS, preparing these data for analysis, building effective prompts, and then using an LLM to generate and deliver feedback.

### 1. Collecting and preparing learner data

Most enterprise or educational LMSs allow you to export or query learner data via an API. The data may include:

*Table 18 Examples of learners' data you can export through your LMS*

<b>Quiz and Question-Level Data</b>	
<b>Objective</b>	Identify specific questions answered correctly or incorrectly, record responses, and match them with correct solutions and rationales.
<b>Typical LMS Access</b>	Export quiz result logs via CSV or use an LMS API endpoint to gather attempts, timestamps, scores, and detailed responses.
<b>Processing</b>	Map each question to its correct solution and rationale. Maintain a record of how many questions each learner answers correctly or incorrectly, and on which attempts.
<b>Assignment Data</b>	
<b>Objective</b>	Determine submission status, timeliness, and grades for each assignment.
<b>Typical LMS Access</b>	Retrieve assignment lists, deadlines, user submissions, and grading details from your LMS.
<b>Processing</b>	Collate each learner's submission dates, highlight if any are late or missing, and note scores or rubrics. Identify patterns (e.g., consistent tardiness, certain rubric criterion not met).

<b>Discussion and Forum Engagement</b>	
<b>Objective</b>	Assess both quantity and quality of participation.
<b>Typical LMS Access</b>	Use discussion-topic endpoints or CSV exports that include each learner's posts, replies, timestamps, and thread participation.
<b>Processing</b>	Count overall posts, detect how many are made weekly, and whether they reflect constructive engagement. Optionally, examine content for length and relevance.
<b>Page Views and Session Data</b>	
<b>Objective</b>	Understand which resources the learner accesses and how frequently.
<b>Typical LMS Access</b>	Many LMSs provide analytics endpoints or summary pages showing hits and participation data.
<b>Processing</b>	Summarise total page views, time spent, and whether learners engaged with recommended modules or topics.
<b>Learner Profile Data</b>	
<b>Objective</b>	Provide personalised context (e.g., job role, years of experience, learning preferences).
<b>Typical LMS Access</b>	Admins can store additional attributes (e.g., from pre-course surveys) and retrieve them.
<b>Processing</b>	Merge profile data such as preferred feedback length or day to tailor both the style and schedule of the feedback.

The collected data forms the backbone of the personalised feedback pipeline. After extracting the relevant information from various data points, compile or transform it into summaries to be fed into the LLM.

## 2. Designing effective prompts for personalised feedback

Crafting prompts that consistently generate meaningful, personalised responses is the foundation of effective automated and personalised feedback. Well-designed prompts should guide the AI system in comprehensively analysing student work while maintaining a supportive and constructive tone. The prompt structure should incorporate context about the assignment, student background, and specific learning objectives to ensure relevance and accuracy.

When designing prompts, begin with a clear system message that establishes the AI's role as an educational feedback provider. This message should emphasise the importance of balancing encouragement with constructive criticism. Follow this with detailed context about the assignment and other student work, including any relevant rubrics or learning objectives. The instruction section should guide the AI through a structured feedback process that includes specific strengths, areas for improvement, and actionable next steps.



### Guidelines for developing prompt structure

#### 1 Start with a clear system message

- Clearly specify the role of the AI (e.g., "You are a learning advisor").
- Emphasise balancing encouragement with constructive criticism.

#### 2 Provide detailed context

Include information on the assignment, student work, rubrics, and learning goals for AI.

#### 3 Give structured instructions to guide AI

Specify that the AI must identify specific strengths with examples, highlight areas of improvement, and offer clear and actionable next steps.

#### 4 Specify detail level

The prompt should also specify word count or detail level, e.g., "short summary," "medium with examples," or "long form with extended guidance".

Table 19 illustrates an example of using LLM for a sample assignment. Annex B provides more examples of LLM prompts used for personalised feedback.

*Table 19 Sample assignment feedback template using LLM*

</>	<b>LLM prompt: Generating personalised learning path</b>
<p>System: You are an educational feedback assistant focused on providing constructive, specific feedback. Your feedback should balance encouragement with areas for growth.</p> <p>Context: {assignment_description}          Student Work: {submission_content}          Previous Feedback History: {previous_feedback}</p> <p>Instructions:</p> <ol style="list-style-type: none"> <li>1. Identify 3 specific strengths, citing examples from their work</li> <li>2. Suggest 1 concrete area for improvement</li> <li>3. Provide 2-3 actionable next steps</li> <li>4. End with an encouraging closing statement</li> </ol>	

6b	<b>Considerations</b>
<p><b>1 Incorporating performance metrics or specific business goals for industry training</b></p> <p>For example, include targets such as “improve customer engagement” or “enhance negotiation skills” to align the feedback with organisational objectives.</p>	

### 3. Tone and style considerations

The tone of automated feedback significantly impacts its effectiveness. Feedback should maintain a professional yet supportive voice that encourages growth and engagement. Use language that acknowledges effort and potential while providing clear direction for improvement. Avoid overly casual or authoritative tones that might diminish the feedback's educational value. In industry settings, this means balancing a respectful, business-like tone with actionable recommendations that directly contribute to performance improvements and overall business objectives.

Writing should be clear and direct, using active voice and specific examples from the student's work. This specificity helps students understand what they did well and what needs improvement. Transition phrases help create a logical flow between different aspects of the feedback, making it easier for students to follow the progression from strengths to areas for growth.



#### Guidelines for tone and style considerations

##### 1 Use a supportive and respectful tone

Feedback should motivate learners, not discourage them.

##### 2 Be specific by referencing parts of the learner's work

Instead of "Your essay was good," say:

"Your analysis of environmental factors demonstrated strong critical thinking, particularly in your discussion of urban pollution patterns."

##### 3 Avoid overly generic statements

Instead of "You need more sources," say:

"To improve your safety audit, consider incorporating recent OSHA guidelines and best practices."

#### 4. Creating actionable feedback

Effective feedback must be actionable, providing students with clear, specific steps for improvement. Begin with a personalised greeting that acknowledges each student and their work. When discussing strengths and improvement areas, reference specific portions of their submission. Conclude with concrete next steps that are achievable and relevant to the course objectives.



##### Guidelines for feedback structure

- 1 **Start with personalised acknowledgement** by addressing the learners' achievements specifically.
- 2 **Highlight specific strengths with examples** by identifying what they did well and why it is effective
- 3 **Point out areas for improvement with supporting evidence** by connecting the feedback to learning goals, objectives or rubrics.
- 4 **Provide concrete action steps** by suggesting specific, achievable way to improve.
- 5 **End with encouragement** by reinforcing motivation and confidence.

## 5. Automating personalised feedback delivery

Automating the delivery of personalised feedback ensures that learners receive timely, relevant insights tailored to their performance. This process typically involves constructing and sending prompts to an LLM, formatting the returned feedback, and distributing it to learners. While many LMSs provide built-in messaging features, some organisations may prefer alternative communication channels (e.g., corporate email and instant messaging apps). These, too, can be integrated and automated following the same core steps.

 Steps for automating personalised feedback delivery
<b>1 Scheduling</b> Decide how often to generate feedback. For instance, daily, weekly, or after a specific milestone such as an assessment deadline.
<b>2 Building a consolidated prompt</b> Gather and merge all relevant data (e.g., quiz performance, module progress, discussion participation) into one structured prompt that captures the learner's progress, areas of difficulty, and recent activity.
<b>3 LLM call</b> Pass the consolidated prompt to the chosen AI model (e.g., GPT-based services) to generate personalised feedback.
<b>4 Post-processing</b> Once the LLM's output is received, convert or format it as needed, such as plain text, HTML, or a format suitable for direct import into an LMS. If using other communication channels (e.g., email or internal chat systems), the feedback can likewise be formatted accordingly to ensure a consistent learner experience.
<b>5 Message assembly</b> Combine a personalised greeting, the LLM's response, and any standard signature or closing remarks.

## 6 LMS messaging API (or alternative channels)

If an LMS is in use, call its internal messaging or announcement endpoint to send feedback directly to each learner's inbox.

If not using an LMS, automate the delivery via organisational email servers, messaging apps, or custom communication platforms following a similar workflow.

## 7 Tracking

Optionally store each message in a database or log for future reference and analytics.

## 6. Evaluation and continuous improvement

The feedback system should be evaluated on an ongoing basis. Track quantitative metrics and qualitative feedback to assess the system's impact on student learning and engagement. Regularly analysing these metrics helps identify areas for improvement and guides system refinement. Table 20 lists some examples of the different metrics.

*Table 20 Key metrics to track performances*

Metric	Examples	Collection Method
Student Engagement	Discussion participation, assignment completion	Automated tracking
Learning Outcomes	Grade improvements, skill development	Performance analysis
User Satisfaction	Feedback utility, clarity ratings	Student surveys
System Performance	Response time, accuracy	Technical monitoring

Student input is crucial for improving the system. To this end, implement regular feedback collection through surveys, focus groups, and analysis of student responses. Use this information to refine prompt templates, adjust tone and style, and enhance the overall effectiveness of the feedback system.

The feedback system should evolve based on collected data and observed patterns. Prompt templates should be regularly reviewed and updated based on effectiveness metrics and student responses. Language patterns should be adjusted, and feedback structures should be refined. This iterative improvement process will ensure that the system remains relevant and valuable to student learning.



## Considerations

### 1 Creating opportunities for feedback through

- Post-feedback micro-surveys
- End-of-course evaluations
- Student focus groups
- Individual student interviews



## HOW WE IMPLEMENT IN OUR ALS PD COURSE

Our workflow has undergone multiple iterations to suit learners' needs better. We experimented with different styles, tones, and lengths to find the most effective approach. During the testing phase, we conducted surveys and focus groups to gather learner feedback on the PF's usefulness, what they liked, and areas for improvement. Many learners found the PF particularly valuable after completing their quizzes or assessments, as it helped them identify areas for improvement and ways to enhance their skills.

We sent weekly PFs in our course, consolidating their progress not to overwhelm the learners. Figure 18 shows a sample of our weekly PF. We also discovered that preferences for PF length vary among individuals. To accommodate this, we introduced a customisation option at the start of the course, allowing learners to choose their preferred PF length, delivery timing, and other settings (Figure 19).

## PM5101 Week 6 Personalised Progress Feedback

← ↵ :



PM5101 Teaching Team,  
PM5101 Project Management [2420]  
21 Feb 2025 at 12:04

Dear ,

Great work on your steady progress in the course! 🎉 Your early submission of quizzes and strong scores in the Module 03A and 03B quizzes show great dedication. Your structured approach to project management concepts is commendable and aligns well with your background in industrial and management engineering.

### What You Did Well:

- Excellent consistency in keeping up with assignments. Submitting on time and scoring full marks on recent quizzes highlights your understanding of core planning processes.
- Strong engagement with module materials. Your completion of all required materials for Modules 1 to 3B demonstrates an organised approach to learning.
- Prior project experience is an asset. With 11-15 projects under your belt, your ability to apply theory to real-world scenarios is a strength—consider sharing insights in discussions to enrich learning for yourself and others.

### Areas for Improvement:

- ◆ Module 3C & 3D Progress - These modules are crucial for understanding resource, quality, risk, and procurement management. Given your role in manufacturing, these concepts directly apply to product design and development. Prioritise completing the readings and quizzes to stay on track.
- ◆ Discussion Forum Engagement - You've shared insights in the Project Charter discussion, but more participation would be beneficial. Engaging in the Quality, Resource, and Stakeholder discussions would allow you to relate course concepts to manufacturing challenges.
- ◆ Handouts & Additional Resources - The Module 03B and 03C handouts are pending. These documents provide structured frameworks useful for both the course and practical application in your role. Try incorporating them into your reviews.

### Next Steps:

- 👉 Aim to complete Module 03C and 03D materials by early next week. This keeps you aligned with the course pace.
- 👉 Engage in at least one discussion thread. Sharing your manufacturing sector experience in project risk or quality management will strengthen your learning and help others.
- 👉 Reflect on how resource planning applies to your current projects. How do you balance quality, resource constraints, and stakeholder needs?

Keep up the great work! Your strong foundation will be invaluable in the upcoming execution and monitoring modules. Let us know how else we can support your learning 😊.

Best Regards,

Your Friendly PM5101 Teaching Team

Figure 18 Example of PF generated and sent to learner's Canvas inbox

<input type="checkbox"/>	<b>Question 47</b>	1 pts						
<p>Which feedback do you prefer? See the examples below:</p> <table border="1"> <thead> <tr> <th>Short-Length Feedback</th> <th>Medium-Length Feedback</th> <th>Long-Length Feedback</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p><input type="radio"/> Short  <input type="radio"/> Medium  <input type="radio"/> Long</p>			Short-Length Feedback	Medium-Length Feedback	Long-Length Feedback			
Short-Length Feedback	Medium-Length Feedback	Long-Length Feedback						
<input type="checkbox"/>	<b>Question 48</b>	1 pts						
<p>Which day would you like to receive the personalised feedback? It will be sent at noon by default.</p> <p><input type="radio"/> Every Monday  <input type="radio"/> Every Tuesday  <input type="radio"/> Every Wednesday  <input type="radio"/> Every Friday</p>								

Figure 19 Example questions to set PF preference for each learner

— END OF OUR IMPLEMENTATION EXAMPLE —

### 5.3 Exercise: Creating Your PF

This quick-start guide is ideal for new instructors, trainers, or support staff who want to explore the workflow of automated, adaptive feedback without needing extensive technical knowledge.

This guide uses our personalised feedback workflow to generate adaptive, AI-driven feedback in [Google Colab](#). It illustrates the entire process, from data loading to prompt generation and feedback delivery, using sample learner profiles (i.e., sample data).



#### Step-by-step guide

##### 1 Access the notebook

- Open the Colab notebook using the [provided link](#).
- The notebook installs necessary libraries (e.g., OpenAI), sets up the environment, and loads sample data.

##### 2 Set up the credentials (Cell 1)

- In Cell 1, enter your LMS API token and OpenAI API key.
- Replace the demo key with your own if needed.
- Remember to keep your credentials confidential.

##### 3 Load sample data (Cell 2)

- Cell 2 creates a DataFrame with a variety of sample learner profiles.
- Run Cell 2 and check that the printed output shows the sample learner profiles correctly.

#### 4 Build the prompt (Cell 3)

- The *create\_prompt* function incorporates multiple data points: assessment score, focus area, quiz score, assignment status, forum posts, engagement level, progress, job role, and industry.
- The prompt instructs the LLM to provide personalized, actionable tips using a specific tone (e.g., "encouraging").

#### 5 Generate and process feedback (Cell 4)

- The *generate\_feedback* function sends the anonymised prompt to the LLM.
- It then cleans the LLM output by removing markdown symbols (e.g., \*\* for bold, \* for italics) using regular expressions.
- Finally, it appends the learner's name and a signature to the feedback.
- Run Cell 4 to see the complete personalised feedback for the selected learner.

## 5.4 Considerations for PF



### Key considerations for PF

#### 1 Crafting effective prompts for personalised feedback

Explicitly establish the AI's role as a learning advisor or constructive feedback assistant. The AI must be provided with detailed contextual information, including assignment descriptions, student submissions, previous feedback, and specific learning objectives so that the feedback is aligned with educational goals.

#### 2 Ensuring clarity, tone, and style in feedback

Feedback should be professional yet approachable, balancing constructive criticism and encouragement. Acknowledging a student's effort and progress fosters engagement and motivation. Avoid vague feedback such as "Good job!" or "Needs improvement!". Instead, provide detailed insights referencing specific elements of the student's work.

#### 3 Designing actionable and impactful feedback

Effective feedback should follow a coherent and structured format, ensuring that students can easily understand and act on the advice provided, and that feedback provides explicit, specific, and achievable guidance. It should encourage students to reflect on their work and engage in independent learning. Asking guiding questions can help foster critical thinking and self-improvement.

#### 4 Tracking key performance indicators

To ensure the quality and relevance of AI-generated feedback, key performance indicators such as student engagement levels (e.g., assignment completion, participation in discussions), achievement in learning outcomes (e.g., improvements in grades, skill development), and user satisfaction (e.g., clarity and usefulness of feedback) must be tracked. Data collected through surveys and performance tracking should be used to refine prompts and AI-generated feedback.

Additionally, the system should enable customisation of tone (e.g., formal vs. conversational feedback style) and adjustment of detail levels based on learner preference (e.g., short, medium or long feedback).



## Ethical considerations

**When developing AI-driven learning pathways, ethical concerns must be addressed to ensure fairness, inclusivity, and data privacy.**

### 1 Bias mitigation in feedback

- Regular monitoring and analysis of feedback patterns to detect biases.
- Examine language patterns and word choices for fairness.
- Ensure consistent treatment across different learner groups.
- Maintain cultural and linguistic sensitivity.
- Check balanced distribution of positive and critical feedback.

### 2 Learner privacy and data protection

- Implement strict data anonymisation practices and make sure sensitive information is not exposed.
- Implement secure storage practices for feedback history.
- Limit access to student data to authorised personnel only.

## 6 Conclusion

Course developers can enhance learner engagement by incorporating tools like KUR, AQ and PF. They can also optimise resource use and ensure equitable access to professional growth opportunities. This Toolkit is a practical guide to implementing ALS and driving impactful professional learning experiences.

### 6.1 Recommended Reading

A comprehensive account of the development of the ALS framework and the associate case study can be found here:

**Hu, X., Goh, Y. M., & Tay, J. (2024).** Construction professionals' perspectives of adaptive learning adoption: An SEM-machine learning approach. *Engineering, Construction and Architectural Management*.  
<https://doi.org/10.1108/ECAM-07-2024-0896>

## Bloom's Taxonomy

**Adams, N. E. (2015).** Bloom's taxonomy of cognitive learning objectives. *Journal of the Medical Library Association*, 103(3), 152–153.  
<https://doi.org/10.3163/1536-5050.103.3.010>

**Bilon, E. (2019).** Using Bloom's taxonomy to write effective learning objectives: The ABCDs of writing learning objectives. Edmund Bilon.

**West, J. (2023).** Utilizing Bloom's taxonomy and authentic learning principles to promote preservice teachers' pedagogical content knowledge. *Social Sciences & Humanities Open*, 8(1), 100620.  
<https://doi.org/10.1016/j.ssho.2023.100620>

## Developing recommender system

**Thorat, P., Goudar, R., & Barve, S. (2015).** Survey on collaborative filtering, content-based filtering and hybrid recommendation system. *International Journal of Computer Applications*, 110(4), 31–36.  
<https://doi.org/10.5120/19308-0760>

**Ko, H., Lee, S., Park, Y., & Choi, A. (2022).** A survey of recommendation systems: Recommendation models, techniques, and application fields. *Electronics*, 11(1), 141. <https://doi.org/10.3390/electronics11010141>

**Xu, L., Zhang, J., Li, B., Wang, J., Chen, S., Zhao, W. X., & Wen, J.-R. (2024).** Tapping the potential of large language models as recommender systems: A comprehensive framework and empirical analysis. arXiv.  
<https://doi.org/10.48550/ARXIV.2401.04997>

## Developing an adaptive quiz system

**Melesko, J., & Novickij, V. (2019).** Computer adaptive testing using upper confidence bound algorithm for formative assessment. *Applied Sciences*, 9(20), 4303. <https://doi.org/10.3390/app9204303>

**Sharpnack, J., Hao, K., Mulcaire, P., Bicknell, K., LaFlair, G., Yancey, K., & von Davier, A. A. (2024).** BanditCAT and AutoIRT: Machine learning approaches to computerized adaptive testing and item calibration. arXiv.  
<https://doi.org/10.48550/arXiv.2410.21033>

## 6.2 Acknowledgements

This research project is funded by SkillsFuture Singapore under the Workforce Development Applied Research Fund (WDARF) grant [GA21-04]. We extend our heartfelt gratitude to all the participants and organisations who helped with this study and the support from colleagues from SkillsFuture Singapore and NUS Centre for Teaching, Learning and Technology.

We also would like to thank Mr Xuming Zhu, Mr Mark Lam, Mr Tianxiang Lan, Mr Benjamin Chua, Mr Kendrick Chan, Ms Rishikka Devi Manohgaran, and other colleagues for their invaluable contributions to this project. Their dedication, expertise, and support have been instrumental in shaping this work.

## References

- Chen, J. C. (2014). Teaching nontraditional adult students: Adult learning theories in practice. *Teaching in Higher Education*, 19(4), 406–418.  
<https://doi.org/10.1080/13562517.2013.860101>
- Chou, C.-Y., Lai, K. R., Chao, P.-Y., Tseng, S.-F., & Liao, T.-Y. (2018). A negotiation-based adaptive learning system for regulating help-seeking behaviors. *Computers & Education*, 126, 115–128.  
<https://doi.org/10.1016/j.compedu.2018.07.010>
- Corbalan, G., Kester, L., & Van Merriënboer, J. J. G. (2008). Selecting learning tasks: Effects of adaptation and shared control on learning efficiency and task involvement. *Contemporary Educational Psychology*, 33(4), 733–756.  
<https://doi.org/10.1016/j.cedpsych.2008.02.003>
- Essa, S. G., Celik, T., & Human-Hendricks, N. E. (2023). Personalized adaptive learning technologies based on machine learning techniques to identify learning styles: A systematic literature review. *IEEE Access*, 11, 48392–48409.  
<https://doi.org/10.1109/ACCESS.2023.3276439>
- Evans, C., Gbadamosi, G., & Richardson, M. (2014). Flexibility, compromise and opportunity: Students' perceptions of balancing part-time work with a full-time business degree. *The International Journal of Management Education*, 12(2), 80–90. <https://doi.org/10.1016/j.ijme.2014.02.001>
- Fernandes, C. W., Rafatirad, S., & Sayadi, H. (2023). Advancing personalized and adaptive learning experience in education with artificial intelligence. 2023 32nd Annual Conference of the European Association for Education in Electrical and Information Engineering (EAEEIE), 1–6.  
<https://doi.org/10.23919/EAEEIE55804.2023.10181336>
- Gagnon, J. L., & Packard, B. W.-L. (2012). An overwhelming climb: The complexities of combining college, full-time work, and company tuition assistance. *Journal of Career Development*, 39(6), 479–499.  
<https://doi.org/10.1177/0894845310397362>
- Huda, A., Firdaus, F., Irfan, D., Hendriyani, Y., Almasri, A., & Sukmawati, M. (2024). Optimizing educational assessment: The practicality of computer adaptive testing (CAT) with an item response theory (IRT) approach. *JOIV: International Journal on Informatics Visualization*, 8(1), 473.  
<https://doi.org/10.62527/jov.8.1.2217>

- Hwang, G.-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, 1, 100001. <https://doi.org/10.1016/j.caear.2020.100001>
- Knowles, M. S., Holton Iii, E. F., Swanson, R. A., & Robinson, P. A. (2020). *The adult learner: The definitive classic in adult education and human resource development* (9th ed.). Routledge. <https://doi.org/10.4324/9780429299612>
- Kurilovas, E., Zilinskiene, I., & Dagiene, V. (2015). Recommending suitable learning paths according to learners' preferences: Experimental research results. *Computers in Human Behavior*, 51, 945–951. <https://doi.org/10.1016/j.chb.2014.10.027>
- Leow, A., Billett, S., Le, A. H., & Chua, S. (2022). Graduates' perspectives on effective continuing education and training: Participation, access and engagement. *International Journal of Lifelong Education*, 41(2), 212–228. <https://doi.org/10.1080/02601370.2022.2044398>
- Liu, Q., Zhuang, Y., Bi, H., Huang, Z., Huang, W., Li, J., Yu, J., Liu, Z., Hu, Z., Hong, Y., Pardos, Z. A., Ma, H., Zhu, M., Wang, S., & Chen, E. (2024). *Survey of Computerized Adaptive Testing: A Machine Learning Perspective* (Version 2). arXiv. <https://doi.org/10.48550/ARXIV.2404.00712>
- Mavroudi, A., Giannakos, M., & Krogstie, J. (2018). Supporting adaptive learning pathways through the use of learning analytics: Developments, challenges and future opportunities. *Interactive Learning Environments*, 26(2), 206–220. <https://doi.org/10.1080/10494820.2017.1292531>
- Merriam, S. B. (2001). Andragogy and Self-Directed Learning: Pillars of Adult Learning Theory. *New Directions for Adult and Continuing Education*, 2001(89), 3–14. <https://doi.org/10.1002/ace.3>
- Mezirow, J., & Taylor, E. W. (2009). Transformative learning theory. In *Transformative learning in practice: Insights from community, workplace, and higher education* (1st ed, pp. 18–32). Jossey-Bass.
- Moreno-Guerrero, A.-J., López-Belmonte, J., Marín-Marín, J.-A., & Soler-Costa, R. (2020). Scientific Development of Educational Artificial Intelligence in Web of Science. *Future Internet*, 12(8), 124. <https://doi.org/10.3390/fi12080124>
- Pliakos, K., Park, J. Y., Cornillie, F., Vens, C., & Van Den Noortgate, W. (2019). Integrating machine learning into item response theory for addressing the

cold start problem in adaptive learning systems. *Computers & Education*, 137, 91–103. <https://doi.org/10.1016/j.compedu.2019.04.009>

Xie, H., Chu, H.-C., Hwang, G.-J., & Wang, C.-C. (2019). Trends and development in technology-enhanced adaptive/personalized learning: A systematic review of journal publications from 2007 to 2017. *Computers & Education*, 140, 103599. <https://doi.org/10.1016/j.compedu.2019.103599>

## Annex A: Checklists



This checklist is not exhaustive and serves as a guideline to support your process. You are encouraged to review and expand upon it as needed to better suit your specific requirements and objectives.

### — LIST OF CHECKLISTS —

- A. Pre-implementation Check ..... 78
- B. Developing Learning Objectives and Content..... 79
- C. Learner Profiling ..... 81
- D. ALS Development and Integration..... 83
- E. Knowledge Unit Recommender (KUR) Implementation..... 85
- F. Adaptive Quiz (AQ) Implementation..... 86
- G. Personalised Feedback (PF) Implementation ..... 87
- H. Final System Verification for Deployment ..... 88

## A. Pre-implementation Check

### *Learning Management System (LMS) Compatibility*

- Verify that your LMS supports Learning Tools Interoperability (LTI) integration.
- Ensure compatibility with SCORM/API standards for seamless content integration.
- Confirm that your LMS allows real-time data tracking to support adaptive learning features.

### *Assess your technical infrastructure*

- Determine whether you need a cloud-based, on-premises, or hybrid system.
- Ensure adequate server capacity, database management, and network bandwidth to support ALS.
- Implement strong cybersecurity measures to protect learner data.

### *Ensure compliance with data privacy laws*

- Ensure your ALS complies with GDPR, PDPA, and other relevant regulations.
- Implement data encryption, role-based access controls, and anonymisation techniques to safeguard learner data.

### *Engage key stakeholders*

- Identify and involve educators, software engineers, LMS specialists, and industry experts in the development process.
- Establish collaborative workflows and protocols for system updates, bug fixes, and performance monitoring.

### *Define learner profiles and data collection methods*

- Determine the learner attributes you need to collect (e.g., background, learning preferences, prior knowledge).
- Set up a learner profile system that dynamically updates based on user interactions.

## B. Developing Learning Objectives and Content

*Define your learning objectives (LOs)*

- Align LOs with Bloom's Taxonomy to structure learning progression.
- Ensure each objective is specific, measurable, and relevant to professional development.

*Structure your KUs*

- Develop a KU matrix that maps knowledge domains against course topics.
- Ensure logical sequencing, progressing from foundational to advanced concepts.

*Label each module with important metadata*

- Assign a topic to each KU.
- Assign related skill areas to each KU.
- Assign difficulty level for each KU.
- Assign estimated time completion for each KU.
- Assign format type for each KU.

*Create engaging and adaptive content*

- Develop a mix of learning materials:
  - Videos ( $\leq$ 10 minutes per KU)
  - Quizzes and self-assessments
  - Case studies and real-world scenarios
  - Lecture handouts and supplementary reading
- Ensure that content is flexible and personalised, allowing learners to progress at their own pace.
- Use real-life examples, case studies, and scenarios that align with learners' professional contexts.

*Plan for assessment and feedback*

- Design quizzes, case studies, and interactive assessments that align with your learning objectives.
- Provide immediate and personalised feedback to enhance learner engagement.

*Make content accessible and inclusive*

- Ensure compliance with Web Content Accessibility Guidelines (WCAG 2.1).
- Ensure that clear language and logical structuring are implemented.
- Implement features like screen reader compatibility, captioned videos, and adjustable font sizes.

*Provide instructor portal (optional)*

- Implement an administrator site where instructors or assigned persons can easily upload, update, and organise course materials.

## C. Learner Profiling

*Collecting essential learner information*

### **Demographics and professional background**

- Job title and industry
- Years of experience in the field
- Highest qualification and relevant certifications

### **Learning preferences**

- Preferred learning style (e.g., videos, reading, quizzes, case studies)
- Course format preference (e.g., self-paced, instructor-led, hybrid)
- Preferred difficulty level (e.g., beginner, intermediate, advanced)
- Availability and time commitment (e.g., preferred study hours per week)

### **Baseline knowledge and skill levels**

- Self-assessment of current knowledge and skills
- Pre-course assessment or quiz results
- Prior courses or certifications related to the subject matter

*Setting up learner data collection*

### **Pre-course questionnaire**

- Design a structured survey to collect learner details at registration or the start of the course.
- Ensure questions cover demographics, prior knowledge, and learning preferences.

### **Pre-assessment quiz**

- Conduct diagnostic tests to assess baseline skill levels.
- Use results to customise the starting point in the course.

### **Allow learners to update their profiles (optional)**

- Enable learners to modify preferences (e.g., adjust pace, preferred content format).
- Provide an option to update career goals or learning interests as they progress.

*Tracking and monitoring learner progress*

- Track course progress, including completed modules and time spent.
- Monitor quiz scores, assessment attempts, and performance trends.
- Identify areas where learners struggle and suggest targeted resources.
- Measure participation in discussions, peer activities, and forums.
- Log interaction with course materials (e.g., videos watched, quizzes attempted).
- Identify inactive learners and trigger reminders or support messages.

*Feedback collection and refinement*

- Update recommendations based on quiz results and assessment performance.
- Adjust difficulty levels dynamically based on engagement and progress.
- Provide personalised learning paths that evolve as learners advance.
- Allow learners to rate or provide feedback on modules and assessments.
- Gather learner feedback on course difficulty, content relevance, and pace.
- Use collected data to refine content, update learning paths, and improve UX.
- Store all learner-sensitive information securely (such as a protected LMS database with secret keys and access tokens).

## D. ALS Development and Integration

### *Select and configure adaptive features*

- Identify which adaptive learning features best suit your training programme (e.g., Knowledge Unit Recommender (KUR), Adaptive Quizzes (AQ), Personalised Feedback (PF)).
- Ensure these features align with learning objectives, instructional strategies, and learner needs.
- Engage technical staff or service providers to configure the hosting environment.
- Assess system requirements, scalability, and backup solutions to ensure long-term stability.
- Confirm that the ALS software is compatible with the LMS infrastructure.
- Ensure the LMS supports necessary technical integrations (e.g., LTI, SCORM, API calls).

### *Integration and security setup*

- Ensure seamless data exchange between the ALS and LMS for learner tracking, content delivery, and analytics.
- Document key integration workflows and assign technical roles.
- Set up secure connections (HTTPS, TLS/SSL encryption) for data transmission.
- Implement role-based access control (RBAC) to restrict data access.
- Store API keys, access tokens, and learner data securely, following GDPR and other data privacy regulations.
- Regularly audit system logs and permissions to ensure compliance with security best practices.

### *Testing and quality assurance*

- Test ALS functionalities in a controlled environment with sample learners.
- Identify and fix technical bugs, performance issues, and integration errors.
- Validate data flow between ALS and LMS, ensuring accurate learner tracking and adaptive responses.
- Conduct a pilot test with a selected group of learners.
- Evaluate the user experience, navigation, and effectiveness of adaptive features.
- Collect learner and instructor feedback to refine ALS settings and interface.
- Simulate high user traffic to test system scalability.
- Ensure quick content loading times and seamless user interactions.
- Monitor system crashes, lag times, and resource utilisation under different load conditions.

### *Deployment and monitoring*

- Set up Continuous Integration/Continuous Deployment (CI/CD) pipelines for smoother deployment.
- Configure error logging, performance monitoring, and troubleshooting mechanisms.
- Establish a backup and recovery plan to prevent data loss.
- Continuously monitor system performance, security, and learner engagement metrics.
- Assign support teams to handle technical issues and learner queries post-launch.
- Schedule regular system updates, bug fixes, and feature enhancements.
- Gather ongoing learner and educator feedback for refinements.

## E. Knowledge Unit Recommender (KUR) Implementation

### *Content structuring and organisation*

- Map course content into knowledge units (KUs), ensuring a clear prerequisite structure or knowledge matrix for logical sequencing.
- Develop a learning content library, storing all materials in a structured database with appropriate metadata (e.g., topic, difficulty level, estimated completion time).
- Keep KUs concise and focused (e.g., 10 minutes per unit) to enhance learner engagement.

### *Recommender system logic and transparency*

- Define recommendation rules to align learning paths with learner profiles (e.g., skill level, previous knowledge, learning preferences).
- Provide clear justifications for recommendations, explaining why a KU was suggested to promote learner trust and engagement.
- Implement customisation options (optional) that allow learners to adjust recommendations based on time availability, content format, or preferred difficulty level.

### *System testing and deployment*

- Conduct internal testing with a sample group of learners to identify technical issues and performance bottlenecks.
- Perform a usability test with actual learners to evaluate the effectiveness, ease of use, and overall experience.
- Deploy the feature using CI/CD solutions and closely monitor performance post-launch.

## F. Adaptive Quiz (AQ) Implementation

### *Quiz bank development and organisation*

- Build a diverse question bank covering all relevant topics, mapped to specific KUs for structured assessment.
- Develop a pre-assessment quiz to establish a learner's baseline knowledge level and adjust content accordingly.
- Tag each question with metadata, including difficulty level, topic, correct answer, explanation, and related KUs.

### *Adaptive mechanisms and engagement*

- Implement adaptive logic that dynamically adjusts question difficulty based on learner responses.
- Define clear quiz completion criteria, such as:
  - Fixed number of questions
  - Mastery-based termination (e.g., learner reaches a predefined competency threshold)
- Record learner responses with a logging system that tracks interactions, timestamps, and selected answers.
- Include varied question formats (e.g., multiple-choice, scenario-based, case studies) to maintain engagement.
- Implement learning analytics dashboards (optional) for instructors and learners to review quiz performance and progress.
- Enable a question rotation mechanism (optional) to prevent repetition by tracking learner history.

### *System testing and deployment*

- Perform internal testing with a sample learner group to catch technical issues.
- Conduct a usability test to assess learner experience and engagement.
- Deploy the system using CI/CD solutions, ensuring real-time monitoring and performance tracking.

## G. Personalised Feedback (PF) Implementation

### *Feedback system design and logic*

- Determine how feedback will be delivered:
  - Instant system-generated feedback (e.g., quiz or assessment results)
  - Instructor-reviewed feedback (e.g., deeper insights, written feedback)
- Structure-specific, actionable feedback addresses learner strengths and areas for improvement and suggests next steps.
- Provide context in automated feedback, including:
  - Learner responses
  - Correct answers
  - Evaluation criteria (e.g., rubrics)
  - Learner profile data (e.g., job experience, past performance)

### *Customisation and learner engagement*

- Allow learners to customise feedback by choosing:
  - Tone (formal vs. conversational)
  - Level of detail (brief summary vs. detailed explanation)
- Ensure feedback encourages self-reflection and action by providing examples or suggested improvements.
- Maintain a feedback record for each learner to enhance personalisation over time.

### *System testing and deployment*

- Conduct internal testing to fine-tune system responses and catch technical bugs.
- Perform a usability test with learners to validate feedback quality, clarity, and impact.
- Deploy the feature using CI/CD solutions, ensuring continuous monitoring for refinements.

## H. Final System Verification for Deployment

- Verify that all ALS features function correctly, ensuring they operate without critical bugs or unexpected errors.
- Ensure that learning content and materials are fully updated.
- Confirm that all ALS components are well-integrated by testing the entire learning flow from a learner's perspective.
- Verify that data flows seamlessly between different components without errors, missing data, or interruptions.
- Collect feedback from the trial run, resolve identified issues, and make necessary refinements before full deployment.
- Implement a monitoring and notification system (optional) to:
  - Track system errors, crashes, or unusual behaviour.
  - Receive automated alerts for performance issues.
- Allow rapid troubleshooting and learner support.

## Annex B: Sample LLM Prompts

### </> LLM prompt: Generating personalised path

You are an AI Learning Advisor for {course\_name}. This course is divided into {course\_modules}, each containing {knowledge\_areas}. Learners rank their preferences for these modules and knowledge areas, prioritising based on career needs and prior knowledge.

The learner, {learner\_name}, is a {job\_role} with {years\_experience} years of experience in {industry}. Their preferred learning style includes {learning\_preferences}. Their pre-test scores indicate strengths in {strong\_areas} and weaknesses in {knowledge\_gaps}.

Generate a personalised learning path for this learner. The path should:

1. Recommend Knowledge Units (KUs) aligned with their learning gaps and career needs.
2. Prioritise content within a total learning time of {time\_constraint} minutes.
3. Ensure each KU is bite-sized (not exceeding 10 minutes).
4. Return the output in the following format: {preferred\_format}.

Selection Criteria:

- Prioritise modules ranked highest in {course\_modules\_ranking} and {knowledge\_areas\_ranking}.
- Avoid redundant content based on pre-test scores.
- Include a brief rationale for each selected KU, explaining how it benefits the learner.

Strictly adhere to the time constraint and do not exceed {time\_constraint} minutes.

&lt;/&gt;

**LLM prompt: Generating quiz for quiz bank**

From the {uploaded\_document}, develop {number\_of\_questions} high-order thinking {question\_type} tailored for {learner\_type} in {industry} context. Ensure that each question is framed as {question\_requirements} where learners take a role of {job\_role} and must apply {required\_skills} in real-world setting.

Each question must meet the following criteria:

1. Present a challenging, scenario-based problem that requires critical thinking.
2. Include four (4) answer options.
3. Highlight the correct answer.
4. Provide a detailed explanation for the correct and incorrect answers. The explanation should be one paragraph per question.
5. The explanation should begin by confirming why the correct answer is right, followed by "The other options are wrong because...", explaining why each incorrect option is unsuitable.
6. Where relevant, reference {uploaded\_references}.

Example format:

Question 1: (Question)

- A. Option 1
- B. Option 2
- C. Option 3
- D. Option 4

Explanation: Option {correct\_option} is correct because {explanation}. The other options are wrong because {explanation}.

Ensure that the questions are sufficiently difficult and challenge learners to think critically in a {industry} context.

**</> LLM prompt: Discussion participation**

System: You are analysing student participation in online discussions. Focus on both quantity and quality of engagement.

Context: {discussion\_topic}

Student Contributions: {post\_content}

Peer Interactions: {reply\_content}

Instructions:

1. Evaluate depth of topic understanding
2. Assess engagement with peers
3. Identify opportunities for deeper discussion
4. Suggest specific ways to enhance future participation

**</> LLM prompt: Equipment handling feedback**

System: You are an AI assistant specialised in construction training feedback.

Context: {safety\_guidelines}

Student Work: {on-site\_report}

Instructions:

Identify 2-3 specific strengths (e.g., proper handling of tools, adherence to safety protocols).

Point out 1 key area for improvement with reference to industry standards.

Provide 2 actionable steps for immediate improvement.

Conclude with a motivational message emphasising safety and quality.