Adaptive Learning Systems in Saudi Higher Education: A Contextualised Conceptual Framework for Student Engagement

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ABSTRACT

Purpose – This paper develops a theoretical framework linking adaptive learning system (ALS) characteristics to student engagement in Saudi higher education, and specifies how two structural features of Saudi public universities, gender-segregated campuses and an instructor-guided pedagogical tradition, shape that relationship.

Design/methodology/approach – This is a theory-adaptation article. Literature published between 2018 and 2025 was synthesized thematically through constructivist learning theory, self-determination theory, and cognitive load theory to build and refine testable propositions, not to quantify effect sizes or produce a census of the field.

Findings – The paper proposes an integrated framework and states seven propositions. Gender segregation and instructor-guided tradition are specified as moderators of the ALS to engagement relationship rather than as barriers, and Arabic language processing quality is specified as a boundary condition. A qualitative gap analysis identifies where the evidence base constrains implementation decisions.

Practical implications – A phased implementation sequence and a course level decision checklist translate the framework into institutional and classroom practice, with the first phase designed as an empirical test of the framework's central mediation claim rather than as a rollout.

Originality/value – The paper reframes two features of Saudi higher education usually treated as demographic controls or generic barriers into specified, falsifiable moderators, and states the resulting propositions explicitly so that they can be confirmed or refuted by future empirical work.

Keywords: Adaptive learning, Student engagement, Higher education, Saudi Arabia, Gender segregation, Conceptual framework

INTRODUCTION

Higher education institutions worldwide are using educational technologies to personalize learning and support engagement. Among these, adaptive learning systems (ALS) represent an important advance. ALS use artificial intelligence, machine learning, and learning analytics to adjust content, feedback, assessment, and learning pathways to individual student needs and performance in real time (Walkington and Bernacki, 2020). Unlike traditional learning management systems that deliver the same sequence to all learners, ALS aim to create responsive environments that adapt to each student's progress. The idea has a long lineage in work on adaptive hypermedia, which established the core logic of modelling the learner and adjusting presentation accordingly (Brusilovsky, 2001).

This shift reflects wider changes in universities. Institutions are expected to support diverse cohorts with varied preparation, language proficiency, and digital skills, while managing large enrolments and pressure to improve retention. ALS have therefore been promoted as a way to offer targeted support at scale (Kulik and Fletcher, 2016).

In Saudi Arabia, digital transformation has accelerated, driven by Vision 2030 and related programmes, namely the Human Capability Development Program, the National Strategy for Data and Artificial Intelligence, and the Saudi Data and AI Authority (SDAIA). Universities have invested in online infrastructure and AI applications, especially after the COVID-19 pandemic (Khan et al., 2022). Recent bibliometric evidence indicates that publications on AI in Saudi higher education grew sharply after 2022, reaching a peak in 2025 (Alqurni, 2026). Most of these studies focus on acceptance models such as TAM and UTAUT and on tools like ChatGPT (Al-Mamary *et al.*, 2024; Faisal, 2024).

Much of the earlier ALS research comes from Western contexts (Ma *et al.*, 2014). Although findings are generally positive, effectiveness is not culturally neutral. Engagement with adaptive systems is shaped by pedagogical traditions, institutional culture, language, infrastructure, and learner expectations (Srite and Karahanna, 2006). Saudi universities operate within a distinct setting characterized by instructor-guided traditions, collectivist values, gender-segregated campuses, Arabic as the primary medium of instruction, and considerable diversity between elite research universities and regional institutions. These factors raise important questions about culturally responsive implementation.

Acceptance studies have grown, and recent empirical work has begun testing AI-driven tools against engagement using acceptance and motivation-based models in Saudi samples (Al-Dokhny *et al.*, 2024; Jallali *et al.*, 2026; Al Taqataq *et al.*, 2025). This evidence base has not yet developed a framework that treats Saudi structural features, specifically gender segregation and instructor-guided pedagogical tradition, as moderators of the ALS to engagement relationship rather than as control variables or generic barriers, nor translated the accumulating evidence gaps into a prioritized, sequenced agenda for institutional practice. This paper addresses that gap through a conceptual analysis of how adaptive learning may influence engagement and autonomy under Saudi institutional and cultural conditions.

The paper makes three contributions. First, it traces pathways from ALS features through theoretically grounded mechanisms to outcomes. Second, it positions Saudi contextual factors as moderators that alter the strength and form of the relationship between ALS and engagement. Third, it develops a context-sensitive implementation matrix.

The remainder of the paper is organized as follows. The conceptual framework, its theoretical anchors, and seven testable propositions are presented first, followed by a review of engagement dimensions. The analysis then situates ALS within the Saudi context, discusses implementation challenges, and presents a qualitative gap analysis. Implications for course level and institutional practice, the implementation matrix, and the sequencing logic close the paper.

Method of conceptual analysis

This is a theory-adaptation article in the sense set out by Jaakkola (2020): its purpose is to build and refine theoretical propositions, not to quantify effect sizes or produce a census of the field. Literature served as raw material for conceptual development rather than as a dataset, so no systematic review protocol or formal quality appraisal was applied, and the paper advances no claim that would require either; readers seeking a fully bounded, PRISMA-reported account of this literature can consult Alqurni (2026), a systematic review of AI in Saudi higher education conducted independently of this analysis. Literature was identified through Scopus and Web of Science searches for 2018 to 2025 using terms including adaptive learning, personalized learning, student engagement, self-determination theory, cognitive load theory, Saudi higher education, and Arabic NLP. Screening proceeded in two stages. An initial title-and-abstract pass retained records with an explicit contribution to ALS, engagement, or Saudi higher education policy and removed conference abstracts without full text, non-peer-reviewed commentary, and K-12 studies; a full-text pass then read the retained records against the three theoretical anchors and the engagement dimensions described below and coded them thematically. This was a deliberate choice, not an omission: the paper is explicitly framed as a theory-adaptation article rather than a systematic review, and PRISMA-style record counts are a feature of the latter design, not the former. Because records were added iteratively as the conceptual model took shape, rather than retrieved once against a fixed protocol and then screened in stages of fixed size, no single count of records screened or excluded at each stage was generated during the search, and inventing one now would misrepresent how the search was actually

conducted. What can be reported, and is reported above, is the search terms, the databases, the date range, and the inclusion and exclusion rationale applied at each pass; a reviewer who needs a bounded, countable record of the search process should treat this as a limitation of the design choice and consult Alqurni (2026) instead. Arabic language sources were screened via English abstracts, which limits access to Arabic-only findings and is noted as a limitation. Analysis involved thematic synthesis. Retrieved sources were read and iteratively coded against the three theoretical anchors and the engagement dimensions described below, linking ALS characteristics to engagement mechanisms and identifying contextual moderators. This process yielded the seven propositions stated below and the qualitative gap analysis in Table I. Neither output is a statistical summary of the literature, and neither should be read as one.

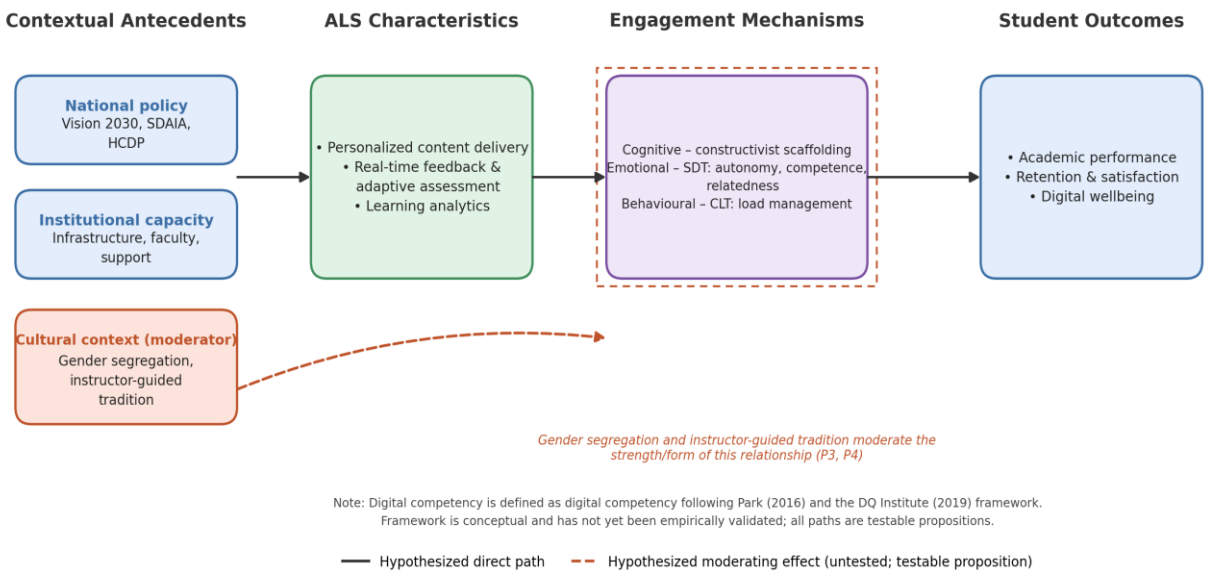
The analysis draws only on published literature and publicly available policy documents. It involved no human participants, no personal data, and no institutional data collection, so ethics approval was not required. The empirical designs proposed later in the paper would require approval from the relevant institutional review bodies before any implementation.

Three kinds of claim appear in what follows, and each is marked as such throughout instead of being folded into a single undifferentiated register. Evidence-supported findings restate results from cited empirical studies, most conducted outside Saudi Arabia and reported with the sample, design, and population qualifications of the original source. The seven propositions stated below are theoretically derived: each follows from the theoretical anchors and the pattern of evidence summarised in Table I, but none has been tested in a Saudi setting, and this paper repeats that caveat at each occurrence instead of stating it only once at the outset. A smaller number of passages extend an existing construct beyond the scope in which it was originally developed – for example, treating gender-segregated campuses as activity spaces in the sense used by McChesney *et al.* (2025), or treating segregation and instructor-guided tradition as moderators rather than as controls. These are the authors' interpretive contributions; they are flagged as such where they occur and carry the least evidentiary weight of the three.

Conceptual framework

Figure 1 presents an integrated framework that places ALS characteristics within Saudi-specific contextual antecedents. It links three contextual domains, national policy, institutional capacity, and cultural context, to ALS characteristics, student engagement, mediating mechanisms, and student outcomes.

Figure 1 Conceptual framework: ALS characteristics, engagement, and Saudi contextual moderators



Note: Digital intelligence is defined here as digital competency, following Park (2016) and the DQ Institute (2019) global standards framework, referring to the ability to use digital tools effectively for learning.

Recent preliminary evidence from Saudi Arabia suggests that digital competency may mediate ALS effects: the fully mediated indirect pathway from adaptive learning through digital competency to sustainable learning outcomes reached $\beta = 0.29$ ($p < .001$), against a non-significant direct pathway of $\beta = 0.11$ (Alruwaili *et al.*, 2025), though this comes from a single study of female students and should be treated as preliminary until replicated. Related mediation and moderation involving engagement and AI-driven tools has also been reported in adjacent Saudi samples using different measures (Jallali *et al.*, 2026), lending indirect, non-identical support to the broader proposition that competency-related factors channel AI tool effects on outcomes, though no study has yet replicated this specific pathway. The priority placed on digital competency in the sequencing recommendations below should therefore be read as provisional, not as an established regularity.

Theoretical anchors

The framework draws on three traditions, each mapped to a part of the model.

Constructivist learning theory (Vygotsky, 1978) underpins the link between adaptive delivery and cognitive engagement: because constructivism treats learning as active construction rather than passive reception, it justifies real-time adaptation to current understanding rather than fixed content, and it grounds the role ALS analytics can play in making a student's own progress visible.

Self-determination theory (SDT; Deci and Ryan, 2000) underpins the link to emotional engagement. Its core claim, that motivation depends on perceived autonomy, competence, and relatedness, explains why self-paced progress and calibrated feedback may raise satisfaction, and why a system that feels surveillant rather than supportive could undermine autonomy instead. Relatedness is the dimension most at risk in individualized digital settings unless collaboration is intentionally designed, which matters in Saudi contexts where collectivist values place particular weight on belonging (see Ryan and Deci, 2017).

Cognitive load theory (CLT; Sweller, 1988) underpins the link to behavioural engagement: by matching difficulty to readiness, adaptive assessment keeps intrinsic and extraneous load within manageable limits, supporting sustained time on task, while spaced practice and worked examples support the germane load that builds durable understanding.

Recent work integrates CLT and SDT, showing that load reduction strategies and autonomy support are complementary rather than opposing (Martin and Evans, 2018; Martin *et al.*, 2021). This integration informs the framework.

Cultural and institutional moderators

Gender segregation and instructor-guided tradition are positioned as moderators rather than barriers: these features change the strength or shape of the ALS to engagement relationship without necessarily reducing it. This positioning is not asserted from first principles; it follows from specific findings. Gender segregation is treated as a moderator, not a fixed barrier, because segregated female sections have been shown empirically to differ from male sections in access to instructor expertise, technical infrastructure, and instructional format, with female students reporting specific supports and challenges tied to that structural arrangement rather than to gender as such (Aldosemani et al., 2024); adaptive systems could plausibly perform differently across male and female campuses if resourcing or training differ systematically along the same lines, an empirical question current evidence gaps leave unanswered. Instructor-guided tradition is treated as a moderator on similar grounds: a document-and-survey study across five Saudi universities classified prevailing pedagogy as predominantly teacher-centred rather than learner-centred and tied that classification to explicit curricular and training gaps (Abdullateef et al., 2023), which grounds the "instructor-guided" label in a specific finding instead of leaving it as a cultural generalisation; students accustomed to that tradition may initially experience self-paced progression as a loss of relatedness even as autonomy increases, suggesting a non-linear trajectory consistent with self-determination theory's account of relatedness under threat (Ryan and Deci, 2017). In the absence of direct comparative evidence linking either feature to ALS engagement specifically, this paper treats both as testable moderators rather than as established effects.

Propositions

The framework yields seven propositions. They are stated so that each can be supported or contradicted by evidence a Saudi institution could realistically gather, and they define what would count as disconfirmation. None has yet been tested in this setting.

P1. Adaptive sequencing, immediate corrective feedback, and difficulty calibration relate positively to behavioural, cognitive, and emotional engagement, and these relationships operate through load management, metacognitive visibility, and satisfaction of competence and autonomy needs rather than through exposure to the technology as such.

Evidence basis and operationalization: the claim draws on meta-analytic support for intelligent tutoring systems generally (Ma et al., 2014), a scoping review reporting increased engagement in roughly a third and increased performance in roughly three-fifths of the studies it covered (du Plooy et al., 2024), and work integrating cognitive load theory with self-determination theory (Martin and Evans, 2018; Martin et al., 2021); none of this evidence is Saudi-specific. It could be tested with multi-item behavioural, cognitive, and emotional engagement scales (e.g., adapted from Fredricks and McColskey, 2012) administered alongside a cognitive load measure and a basic psychological needs satisfaction instrument, modelling load and needs satisfaction as mediators rather than treating platform exposure as a direct predictor.

P2. Student digital competency mediates the relationship between ALS use and engagement. Where competency is low, the direct effect of ALS on engagement approaches zero, so competency functions as a precondition rather than as a covariate.

Evidence basis and operationalization: the only direct support is a single Saudi mediation study among female students in which the indirect effect of digital competency exceeded the direct effect of ALS use (Alruwaili et al., 2025); the finding is unreplicated and drawn from one gender and one institution. It is operationalized directly in the Phase 1 design specified below: matched cohorts assigned to scaffolded and unscaffolded competency-building conditions, with competency and engagement measured at entry and exit and mediation tested formally rather than assumed.

P3. Campus gender segregation moderates the ALS to engagement relationship. The moderation operates through resourcing, technical support, and training parity rather than through student gender itself, and it should therefore disappear when parity is achieved and persist when it is not.

Evidence basis and operationalization: no study has tested this moderation directly; the claim is grounded in evidence that segregated instruction changes students' access to instructor expertise and infrastructure (Aldosemani et al., 2024), while resourcing parity across male and female sections specifically has not been documented empirically and remains an open question. It could be operationalized through matched quasi-experimental parallel implementation across male and female campuses, coding resourcing and training parity as the moderator, comparing engagement under parity and non-parity conditions, and securing ethical approval before any data collection involving students.

P4. Instructor-guided pedagogical tradition moderates the relationship in a non-linear form. Students accustomed to explicit direction show an initial decline in relatedness and emotional engagement when moved to self-paced progression, followed by recovery as self-regulation develops, producing a trajectory that single-timepoint designs cannot detect.

Evidence basis and operationalization: the teacher-centred baseline is documented empirically across five Saudi universities (Abdullateef et al., 2023), and the predicted dip in relatedness follows from self-determination theory's account of autonomy shifts threatening relatedness (Ryan and Deci, 2017); the recovery trajectory itself has not been measured. It requires a repeated-measures design tracking relatedness and emotional engagement at three or more points across a semester, since a single-timepoint or pre-post design would read a genuine dip-then-recovery pattern as a simple decline.

P5. Arabic natural language processing quality operates as a boundary condition. Where feedback generation for Arabic-medium instruction is less accurate than for English, cognitive engagement and perceived competence are attenuated for Arabic-medium students independently of platform pedagogy.

Evidence basis and operationalization: technical limitations of Arabic NLP relative to English are documented for morphologically rich, lower-resource languages generally (Al-Rfou et al., 2013; ElSabagh et al., 2025), against recent gains from Arabic-centric models (Sengupta et al., 2023; Bari et al., 2024); no study has yet linked NLP accuracy to engagement outcomes. It could be operationalized through disaggregated evaluation of feedback accuracy for Modern Standard and dialectal Arabic input, correlated with cognitive engagement and perceived-competence scores for Arabic-medium versus English-medium students using the same platform.

P6. Blended designs that retain instructor mediation and structured collaboration produce stronger engagement than fully automated adaptive delivery in settings where instructor authority and collective learning are valued, and the advantage is largest for the relatedness component of need satisfaction.

Evidence basis and operationalization: the PMAISE model's finding that pedagogical mediation shapes the relationship between AI tools and engagement (Long et al., 2025) is consistent with the teacher-centred baseline documented by Abdullateef et al. (2023); the relatedness-specific advantage is a theoretical extension of that finding, not yet measured directly. It could be tested by comparing blended and fully automated delivery arms on the relatedness subscale of a validated need-satisfaction instrument while holding platform and content constant across arms.

P7. Algorithmic engagement metrics that reward rapid independent progression systematically under-detect collaborative sense-making and help-seeking. Where those behaviours are culturally valued, system-generated engagement scores will diverge from instructor and peer judgements of the same students.

Evidence basis and operationalization: the claim rests on conceptual critiques of algorithmic engagement metrics and reductionist tracking (Selwyn and Gasevic, 2020) and on bibliometric evidence that explainability remains underdeveloped relative to predictive work in this literature (Talmoudi and Choukir, 2026); no study has directly compared system-generated and human-judged engagement scores for the same students. It could be operationalized by collecting system-generated engagement scores alongside independent instructor or peer ratings for the same cohort and analysing divergence against self-reported collaborative and help-seeking behaviour.

P2 carries the sequencing logic presented later, and it rests on a single unreplicated study. P3 and P4 are the paper's principal contribution, since they convert two features usually recorded as barriers or controls into specified, falsifiable moderation claims.

Student engagement in adaptive learning environments

Dimensions of engagement

Student engagement is one of the strongest predictors of success in higher education: engaged students are more likely to persist, participate, achieve higher outcomes, and report satisfaction (Kahu and Nelson, 2018). Engagement is commonly understood through three reinforcing dimensions: behavioural (participation, attendance, time on task), cognitive (self-regulated learning and deep processing; Zimmerman, 2002), and emotional (motivation, enjoyment, confidence; Fredricks *et al.*, 2004; Fredricks and McColskey, 2012; McChesney *et al.*, 2025).

Recent models extend the traditional ABC model: the ABC plus model incorporates activity spaces and distinguishes affective valences (McChesney *et al.*, 2025), while the PMAISE model maps how pedagogical mediation shapes the relation between AI tools and engagement (Long *et al.*, 2025). The activity-space concept, originally denoting different settings within a single course such as lectures and independent study, suggests a further extension, offered here as an application of the construct beyond its original scope rather than a claim the model already makes: gender-segregated campuses may constitute distinct activity spaces with different

resourcing, peer dynamics, and instructor availability, so the same ALS feature could generate different affective valences on different campuses purely as a function of the space encountered rather than the technology itself. This reframes gender segregation as a structural condition rather than a demographic control variable, reinforcing the moderator framing adopted above, though whether the construct behaves at campus scale as it does at course scale remains an open empirical question.

How adaptive systems may influence engagement

ALS may influence all three dimensions through different mechanisms: personalized pace can support behavioural engagement by reducing frustration for struggling learners and providing challenge for advanced learners; dashboards, progress indicators, and automated feedback support cognitive engagement by encouraging strategic learning; and emotional engagement may be supported through increased competence and autonomy when challenges are calibrated and feedback is immediate, since success at appropriate levels builds confidence.

Evidence from a scoping review of 69 studies found that 36% reported increased engagement and 59% reported increased performance, although reporting was inconsistent (du Plooy *et al.*, 2024).

Challenges to engagement

ALS can also create difficulties: some students may find adaptive environments isolating when instructor and peer interaction is reduced, emotional engagement may decline with technical problems or poor interfaces, and students familiar with teacher-directed learning may need time to develop self-regulation. Engagement metrics also need scrutiny, since if good engagement is defined algorithmically as rapid independent progression, systems may disadvantage students who prefer collaborative sense-making or who seek clarification before advancing, definitions that may not align with the guided instruction and peer discussion often valued in Saudi contexts.

Adaptive learning in the Saudi higher education context

Policy environment and institutional interest

Saudi higher education is undergoing rapid digital transformation under Vision 2030. The Human Capability Development Program aims to prepare citizens for future labour markets, while the National Strategy for Data and Artificial Intelligence encourages AI integration. SDAIA coordinates national capability building in data and AI, including a target of training 40 percent of the workforce in basic data and AI literacy (Saudipedia, 2025). The Kingdom also rose 25 places to sixth globally out of 193 countries in the 2024 United Nations E-Government Development Index (United Nations, 2024). These frameworks legitimize investment in personalized infrastructure.

Institutional reports describe adaptive technologies entering university courses as part of wider e-learning strategies, though adoption remains uneven across institutions, reflecting sector diversity (Khan et al., 2022).

Gender-segregated campuses

A distinctive feature of Saudi public higher education is gender segregation: most public universities operate parallel male and female campuses or sections, with female sections sometimes using video-linked instruction or separate infrastructure, so ALS must function effectively across potentially differing technical environments. Institutions should ensure equivalent access to hardware, technical support, and training for female students and faculty. The clearest local documentation of this gap comes from a study of Saudi female students in male-instructor-taught online courses, which found that segregation itself, rather than gender, shaped students' experience of teaching presence and identified faculty training as the main lever available to institutions (Aldosemani et al., 2024); comparative research across campuses using adaptive systems specifically is currently lacking, leaving a significant evidence gap.

Institutional diversity

The sector spans research intensive universities in major cities and smaller regional institutions with different resource levels, faculty expertise, connectivity, and digital literacy; a uniform approach risks widening gaps between well-resourced and under-resourced institutions.

Pedagogical traditions

Saudi educational culture has often emphasized instructor authority, structured guidance, and collective learning; a document-and-survey study across five Saudi universities confirms this empirically, classifying prevailing pedagogy as predominantly teacher-centred and linking that classification to specific gaps in curricula, teaching methods, and faculty training (Abdullateef et al., 2023). Students accustomed to explicit direction may initially experience algorithm-generated pathways as disorienting, suggesting a non-linear adjustment trajectory. Blended approaches combining adaptive technology with instructor support and collaborative activities may be especially effective, with the instructor mediating between system and student and providing connection that technology alone cannot offer.

Challenges of adaptive learning implementation

Arabic language and cultural responsiveness

Arabic presents technical challenges due to complex morphology, derivational systems, dialect variation, and contextual structures that complicate processing (ElSabagh *et al.*, 2025). Recent Arabic large language models such as Jais (Sengupta *et al.*, 2023) and ALLaM (Bari *et al.*, 2024) have improved performance, but many adaptive platforms remain trained mainly on English data, a long-standing difficulty since multilingual representation work shows languages with rich morphology and limited annotated resources are served less well by English-optimized models (Al-Rfou *et al.*, 2013); if Arabic NLP accuracy is lower, students may receive lower quality feedback, creating systematic disadvantage. Cultural responsiveness extends beyond language: examples, scenarios, and interaction patterns should reflect learners' social contexts rather than imported models alone.

Faculty readiness and professional development

Successful implementation requires instructors to integrate technology meaningfully. Faculty need development in instructional design for adaptive environments, analytics interpretation, self-regulated learning support, and culturally responsive digital pedagogy; without support, faculty may perceive ALS as extra workload, and the role shift from content deliverer to facilitator and learning designer requires training and institutional backing.

Student adaptation to autonomous learning

Although ALS aim to personalize, they also require greater learner responsibility: students must interpret feedback, manage schedules, monitor progress, and seek help, exercising the diagnostic and self-managing capacities that define self-directed learning (Garrison, 1997). Orientation programmes, digital literacy support, and scaffolded guidance that gradually builds self-regulation are advisable for students transitioning from structured environments. A recent randomized experiment with female Saudi EFL learners found that a personalized AI-driven platform produced significant gains in perceived adaptability, learner autonomy, and retention relative to a static control, offering early evidence that autonomy support is achievable in this population, though the finding awaits replication across disciplines and male cohorts (Al Taqataq *et al.*, 2025).

Equity and access

Implementation may widen inequalities if benefits depend on digital competency, as recent research suggests (Alruwaili *et al.*, 2025): students with lower digital literacy may benefit less, potentially increasing achievement gaps, and within Saudi Arabia equity concerns are heightened by regional infrastructure differences and gender-segregated structures. Equitable implementation requires reliable infrastructure, device access programmes, digital literacy services, and alternative pathways for students facing barriers.

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Datafication and algorithmic governance

Much adoption-focused literature rarely engages critical scholarship on datafication. Adaptive systems track clicks, pauses, navigation, and help-seeking, creating detailed behavioural profiles; Selwyn and Gasevic (2020) note risks of reductionism, deficit framing of at-risk students, and normalization of continuous tracking, while Williamson (2017) argues personalization discourses have sometimes served as commercial framing devices independent of evidence strength. Recent bibliometric work on explainable AI in higher education similarly finds transparency and interpretability an underdeveloped theme relative to predictive research, reinforcing the need for governance frameworks that make ALS recommendation logic auditable rather than opaque (Talmoudi and Choukir, 2026).

For Saudi Arabia, this lens raises two concerns. First, continuous tracking raises data governance questions where student data intersects with family and institutional oversight. Second, personalization trained mainly on non Arabic, non Gulf datasets may embed bias into what counts as typical or at risk. Institutions should establish clear governance for privacy, transparency, and equitable access, ensuring that protections apply equally across male and female campuses.

Evidence gaps and research priorities

Table I presents a qualitative gap analysis produced through the thematic synthesis, with gaps ordered by how directly each constrains implementation decisions. The table characterizes the state of the evidence; it does not count it. No prevalence estimates are offered, because the search underpinning this paper was not systematic and could not support them. Establishing the actual distribution of study designs, durations, and disciplines would require a registered scoping review, which the priorities below identify as a research task in its own right.

Table I Qualitative gap analysis of the adaptive learning evidence base for Saudi higher education

Priority	Evidence gap	Current state	What is needed	Implementation impact
Critical	Digital competency development	One mediation study with female students; no intervention research	Quasi-experimental studies testing digital literacy interventions	Directly blocks evidence-based rollout
Critical	Faculty development effectiveness	Widely cited but rarely evaluated	RCT or matched comparison of professional development interventions	Blocks faculty training planning
Critical	Gender comparative implementation	No comparative studies across male and female campuses	Matched quasi-experimental parallel implementation with ethical approval	Blocks equity assurance
Critical	Longitudinal outcomes	Study designs predominantly span a single semester or less	3- to 5-year cohort tracking of retention, graduation, and career outcomes	Blocks understanding of sustained effects
High	Arabic NLP quality	Challenges described but limited performance data	Evaluation of MSA and dialectal Arabic processing in adaptive platforms	Constrains platform selection
High	Algorithmic fairness	Conceptual concerns but no empirical audits	Analysis of recommendation patterns by student demographics	Constrains ethical assurance

High	Discipline-specific effects	Concentrated in STEM subjects; evidence from humanities and Arabic language disciplines very limited	Multi-site studies in Arabic language, Islamic studies, and social sciences	Constrains generalizability
Moderate	Self-regulation readiness	Baseline autonomous learning skills unknown	Assessment of student self-regulation capabilities	Limits optimization
Moderate	Cost-effectiveness	No return on investment data for Saudi contexts	Comparative cost-effectiveness analysis	Limits resource allocation
Moderate	Distribution of the evidence base itself	No registered mapping of ALS study designs, durations, or disciplines	Registered scoping review with PRISMA reporting	Constrains all prioritization, including this table

Note: Entries characterize the state of the evidence as encountered during thematic synthesis. They are not prevalence estimates and should not be read as a systematic census. ALS = adaptive learning systems; MSA = Modern Standard Arabic; NLP = natural language processing; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT = randomized controlled trial.

Implications for university teaching practice

Evolving instructor roles

Rather than replacing instructors, ALS transform their roles: instructors increasingly act as facilitators, mentors, and interpreters of analytics, and by automating routine corrective feedback, ALS can free instructors to focus on conceptual clarification, higher-order discussion, and individual support.

Curriculum design and blended approaches

ALS are most effective when integrated into broader pedagogical strategies rather than used as isolated tools, combining personalized digital learning with collaborative activities, discussion, and authentic assessment. Blended models are likely more effective than fully automated approaches where students value structured guidance, with ALS handling routine delivery and formative assessment while freeing instructors for higher-order activities.

Learning analytics and data-informed teaching

Adaptive systems generate rich data that can inform practice: dashboards can help identify disengaged students, monitor progress, and target interventions, but effective use requires faculty understanding of data interpretation and ethical considerations, and institutions should establish governance frameworks for privacy, transparency, and equitable access.

Course level application

Institutional readiness matters, but adoption decisions are made course by course, usually by an individual instructor with a fixed syllabus and limited release time. Two practical questions govern that decision: whether the instructor is prepared to mediate an adaptive system, and whether the course design gives the system something useful to do.

Readiness to mediate an adaptive system spans five domains, each tied to a proposition stated earlier. Instructors can usefully ask whether they are able to:

• restructure a topic so that the system verifies prerequisite mastery before class time is spent on it, and identify which outcomes should remain instructor led (P1, P6);

• read a dashboard well enough to distinguish a disengaged student from one progressing quietly and well (P7);

• scaffold pacing decisions for students who have not previously managed their own progression, and normalize the early adjustment period rather than reading it as disengagement (P4);

• judge whether system examples and Arabic language feedback are of usable quality in the discipline concerned (P5);

• design group tasks that build on, rather than duplicate, individual work done in the system (P6).

The second question concerns course design. Table II sets out the decisions worth recording before a term begins, since each is difficult to reverse once teaching is under way. Its logic follows P6: the adaptive system handles routine practice, formative assessment, and prerequisite mastery, while class time is reserved for the conceptual, collaborative, and relational work the system cannot supply. The table also asks instructors to state, in advance, what the engagement dashboard would need to show before an intervention is triggered. Specifying that threshold early guards against the pattern described in P7, in which an algorithmic definition of engagement quietly becomes the instructor's own.

Table II Decisions to record before deploying an adaptive system in a course

Stage	Decision to record before the term begins	Why it matters
Division of labour	Which learning outcomes will the system carry, and which will remain instructor led?	Prevents the system absorbing conceptual work it handles poorly and the instructor duplicating routine practice
Division of labour	What will class time be used for once routine practice moves into the system?	A blended design that does not repurpose contact time yields added workload without pedagogical gain
Entry readiness	How will student digital competency be checked before the system is required?	P2 holds that competency conditions benefit; unchecked, low competency students absorb the cost without the gain
Entry readiness	What orientation will students receive on interpreting feedback and managing pace?	Addresses the adjustment trajectory described in P4
Language and content	Has feedback quality been sampled in the language of instruction for this subject?	P5 treats language processing quality as a boundary condition, not a technical footnote
Engagement definition	What dashboard pattern will trigger an intervention, and what will that intervention be?	Specified in advance the threshold remains pedagogical; specified afterwards it drifts toward whatever the system measures (P7)
Engagement definition	Which valued behaviours will the system fail to record, and how will they be assessed instead?	Collaborative sense-making and help-seeking are usually invisible to progression-based metrics

Relatedness	Where in the week do students work together on shared, non-individualized tasks?	P6 predicts relatedness is where fully automated delivery loses most ground
Evaluation	What will be measured at entry and exit, and what result would lead to discontinuing the system?	A stated stopping rule distinguishes evaluation from advocacy

Note: P1 to P7 refer to the propositions stated earlier in the paper. The table has not been validated and is offered for local adaptation.

Implementation matrix for teaching practice

Table III translates the analysis into actions, with each action linked to evidence or to an identified gap and sequenced into a phased implementation matrix.

Table III Implementation matrix for adaptive learning in Saudi higher education

Dimension	Key actions	Stakeholders	Success indicators	Evidence basis
Student support	Digital competency and self-regulation scaffolding; orientation programmes	Student support services; instructors	Digital competency scores; retention rates; help-seeking frequency	Preliminary digital competency mediation finding needs replication
Faculty development	Professional development in pedagogy, analytics, and culturally responsive teaching	Ministry of Education; national e-learning bodies; universities	Faculty confidence measured by validated scale; integration quality rubrics	Faculty development gap widely cited, not evaluated
Phased implementation	Pilot across diverse institutional types before scaling	University leadership; e-learning units	Pilot success rates; qualitative stakeholder feedback	Regional diversity gap
System localization	Arabic NLP enhancement using recent Arabic LLMs; culturally relevant content	SDAIA; local EdTech developers; universities	Language processing accuracy; engagement metrics disaggregated by language	Arabic NLP gap
Blended models	Combine adaptive technology with instructor interaction and collaborative tasks	Instructors; instructional designers	Satisfaction; engagement measured with validated scale	Instructor guided tradition context
Gender equity	Equivalent resources across campuses; parallel monitoring with privacy safeguards	University leadership	Resource allocation parity; outcomes disaggregated while protecting privacy	Gender segregated implementation gap
Ethics framework	Data privacy; algorithmic transparency; governance	Governance bodies; ethics committees	Student trust survey; regulatory compliance audit	Algorithmic bias and ethics gap

Equity assurance	Infrastructure parity; device access; accessibility compliance	Government; university leadership	Equity metrics; WCAG compliance	Regional diversity gap
Continuous evaluation	Embedded assessment at every phase; evidence-informed iteration	All stakeholders	Evidence generated; decisions documented	Absence of Saudi-specific longitudinal evidence

Note: LLM = large language model; NLP = natural language processing; WCAG = Web Content Accessibility Guidelines.

Sequencing logic

Not all actions can be resourced simultaneously. The sequencing proposed here proceeds in three phases, and its first phase should be understood as a test rather than a rollout.

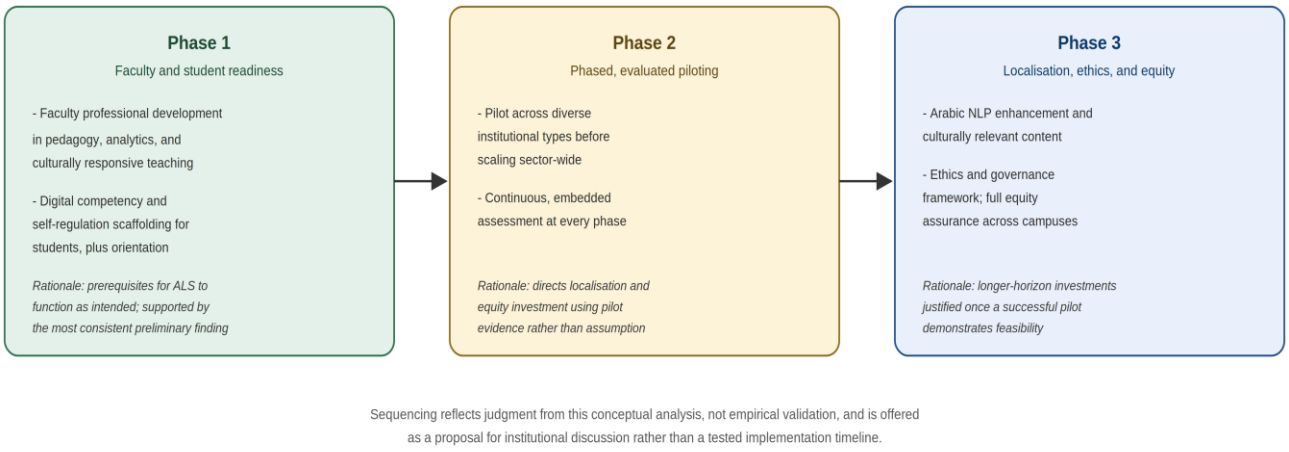
Phase one addresses faculty development and student digital competency scaffolding. P2 is tested first not only because it has empirical support, thin as that support is, but because it is a logical precondition for the other mechanisms: P1, P4, and P6 all describe pathways running through a student's ability to interpret feedback and manage self-paced progression, which presupposes baseline competency, and testing P3 or P4 first risks attributing a competency effect to a moderator effect. Because P2 rests on one unreplicated study, institutions should implement this phase as a quasi-experimental test rather than a proven strategy: assign matched cohorts to scaffolded and unscaffolded conditions, measure competency and engagement at entry and exit, and treat a null result as grounds for moving directly to a test of P3 or P4 instead. Framed this way, the weakest evidence in the paper generates the strongest evidence a university could collect.

Phase two introduces evaluated piloting across institutional types, so that localization and equity investments follow pilot evidence rather than assumption. Piloting in parallel across male and female campuses, with appropriate ethical approval, would simultaneously test P3.

Phase three treats system localization, the ethics framework, and full equity assurance as longer horizon investments that a successful pilot would justify. P5 becomes testable at this point through disaggregated evaluation of feedback quality by language of instruction.

The ordering reflects reasoning from the present analysis, not empirical validation. It is a proposal for institutional discussion and a research design, and it should be revised as each phase returns evidence.

Figure 2 Three phase sequencing logic for institutional implementation



CONCLUSION

Adaptive learning systems offer opportunities for personalized instruction, improved engagement, and flexible pathways, and align with efforts to expand digital education under Vision 2030, but effective implementation requires more than technology adoption.

This analysis has argued that ALS effectiveness depends on pedagogical integration, cultural responsiveness, faculty readiness, and student support, and that ALS may support behavioural, cognitive, and emotional engagement through scaffolding, self-determination support, and load management, mechanisms mediated by institutional culture, pedagogical tradition, language, and learner readiness. Distinctive features of Saudi higher education, gender segregation, instructor-guided tradition, Arabic as primary language, collectivist values, and institutional diversity, are best viewed as moderators requiring design attention rather than as barriers.

The most consistent preliminary empirical pattern is that digital competency may mediate benefits, which the analysis states formally as P2. Students with higher digital competency appear to derive greater benefit than those without, suggesting that competency development may be a precondition. This finding rests on a single unreplicated study, and the first implementation phase is accordingly designed as a test of it rather than as an application of it.

Implementation should proceed in phases, beginning with faculty and student readiness and followed by evaluated institutional pilots. Arabic language quality, culturally responsive design, professional development, and blended approaches that preserve instructor-student relationships all need attention along the way, and critical scholarship on datafication and algorithmic governance should inform each phase so that ALS serve educational goals without reproducing inequities.

Future research should examine adaptive learning within Saudi contexts through empirical studies of student experiences, faculty perspectives, and long-term outcomes; comparative studies across gender-segregated campuses with appropriate ethical safeguards, evaluation of faculty development models, and assessment of Arabic NLP quality and algorithmic fairness represent urgent priorities.

Limitations of this analysis include reliance on English language publications, absence of a systematic review protocol, and dependence on a limited number of Saudi-specific empirical studies. The seven propositions are the paper’s claims, and every one is untested; the framework should be judged on whether those propositions are worth testing, not on whether this analysis has established them. Future work should incorporate Arabic language sources, systematic search procedures, and empirical designs capable of confirming or refuting each proposition in turn.

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