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# The Development and Utilization of an Electronic Assessment Software in Dental Education: A Comprehensive Evaluation

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ABSTRACT

*Purpose/Objectives:* This article introduces the Key Electronic Assessment Platform (KEAP), an electronic-based assessment platform created in-house at the College of Dentistry (COD), King Saud bin Abdulaziz University for Health Sciences (KSAU-HS), Riyadh, Saudi Arabia. It highlights the platform's integral value and demand within the educational system.

*Methods:* The article introduces the KEAP system design and architecture, describes its features, tests, and implementation in addition to its maintenance and security. It also presents the outcomes of KEAP utilization and the level of users' satisfaction.

*Results:* The KEAP item bank has been expanded by more than 26,500 questions over the last four academic years and 1,255 exams have been administered. KEAP provides a highly secure structured framework for assessment planning, conduction, and evaluation. More than 90% of students and faculty are satisfied or very satisfied with their experience using the KEAP system indicating that it is well accepted by the end users.

*Conclusions:* The development of KEAP is based on contextual factors in COD, KSAU-HS with the aim of creating a process for assessment that is valid, efficient, standardized, and highly secure. KEAP's design and successful implementation can provide a successful example of implementing electronic-based assessment in higher education.

## 1 Introduction

The educational system serves as a pivotal mechanism in a nation's development, fostering the growth of its human resources (Handoko et al., 2019). Assessment in education is the gauge for students' attainment of learning outcomes, encompassing their acquired knowledge, cultivated skills, and developed values. Moreover, assessment determines the extent to which educational and institutional objectives have been achieved (Jamil et al., 2012). There are two assessment types; formative (continuous) and summative (mid-of-year or end-of-year) assessments (Daniel, 2020; Gamage et al., 2020). Furthermore, various assessment methods for academic progress such as exams, presentations, and assignments exist (Sim et al., 2004). Significantly, the written examination stands as a universally adopted assessment tool prevalent in academic environments (Gallagher, 2003).

Traditionally, examinations were administered in a manual process that involved the preparation of both examination question papers and corresponding answer sheets. This approach possesses notable shortcomings, such as the challenges in result publication, management of paper scripts, and potential loss of question papers (Reddy MMMR, 2017). In addition, the primary difficulties associated with paper-based assessment methods encompass issues of security and scalability (Sindre and Vegendla, 2015).

Learner's assessment in higher education settings has evolved over

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recent decades. The growing attention toward optimizing quality, efficiency, and objectivity in assessment has led to employing innovative approaches by utilizing advancements of information technology in assessment of learning and for learning. Advancements of information technology allowed the paper-based assessment mode to be transformed into electronic-based assessment mode, overcoming the challenges associated with paper-based assessment and reducing the burden on educators and students (Jamil et al., 2012). The need to customize assessment schemes has become particularly evident during the COVID-19 era, when traditional assessment mode was no longer feasible since universities and colleges suspended in-person activities following the guidance of public health authorities to maintain social distancing (Murphy, 2020; Memon et al., 2021). The shift of assessment mode from paper-based to electronic-based was by far the most prevalent form of assessment transformation observed during that exceptional time and beyond (Memon et al., 2021). Even prior to the pandemic, the strengths and validity of the electronic-based assessment were well known and thus, the utilization of this mode is accepted and advocated (Bunderson et al., 1988; Boitshwarelo et al., 2017; Bearman et al., 2023).

Implementing an electronic-based examination mode offers several advantages. It contributes to efficient exam scoring and reduces grading errors. Moreover, it simplifies exam material distribution, improves its security, enables effective analysis of individual students' performances, allows the employment of extensive question banks, automatically archives records, and reduces cost and time (Mazzeo and Harvey, 1988; Bugbee, 1996; Thelwall, 2000; Paek, 2005; Folk et al., 2006; Handoko et al., 2019). Electronic-based examinations also allow randomization of questions, automated analysis, and immediate feedback (Fluck et al., 2009). They also facilitate storage and handling of assessment data, which are necessary to meet the academic accreditation requirements, like those set by the National Center for Academic Accreditation and Evaluation in Saudi Arabia (Al-Madi et al., 2018; Salama and Al-Balkhi, 2020).

While there are various commercially available assessment software solutions, each with its strengths and limitations, the need for a customized platform became evident due to the unique requirements and objectives of the College of Dentistry (COD) at King Saud bin Abdulaziz University for Health Sciences (KSAU-HS), Riyadh, Saudi Arabia. Existing solutions did not fully align with the specific needs for curriculum mapping, learning outcomes assessment, reporting and secure electronic examinations. This gap necessitated the development of the Key Electronic Assessment Platform (KEAP). KEAP was designed to be highly adaptable and scalable, ensuring it could grow alongside the college and institution's evolving needs. It integrates seamlessly with the existing educational framework and other in-house built software applications, addressing specific challenges such as secure examination administration, comprehensive reporting, and alignment with national accreditation standards.

To appreciate the impact of KEAP on assessment procedures and to recognize its potential eminence as a robust electronic examination platform, the aim of this study is to provide a detailed record of KEAP's development, features, and implementation outcomes. By sharing insights, experiences, and potential lessons, we aim to help other institutions exploring similar digital transitions or improvements. Ultimately, the information presented will serve as a valuable roadmap for developing electronic examination platforms, fostering the appropriate integration of technology in assessment, and appraising the outcomes of its utilization.

## 2 Methods

### 2.1 Research approach

The development and implementation of KEAP in 2017, were driven by a collaborative effort involving the assessment unit, the department of information technology, academic affairs, and the development and quality assurance unit. The team, together with key stakeholders, produced a comprehensive online assessment platform to manage online course mapping, house a question bank, and effectively handle online exam delivery and reporting. The KEAP software development consisted of three phases; KEAP software production, refining, and validation. After several phases of brainstorming sessions and meetings, the web-based application (KEAP) was created.

### 2.2 Implementation

The implementation process followed the 'train the trainer' concept, where comprehensive training was provided to a selected group of users who then trained others. E-learning modules and training manuals were developed for each level of access. Implementation verification was performed by the developer team, and an end-user acceptance test was conducted to confirm that the system was working as desired. The system was considered accepted upon successful completion of the implementation verification and acceptance tests.

### 2.3 Data collection methods

Data on the utilization of KEAP were collected, including the number of courses using the system, the number of students involved, the expansion of the question bank, and the administration of examinations over several academic years. These usage statistics provided a quantitative measure of KEAP's adoption and impact.

Surveys were conducted among faculty members and students to assess user satisfaction with the KEAP system. The surveys consisted of five items related to functionality, interface, support features, ease of use, and overall satisfaction, using a five-point Likert scale. These surveys provided qualitative data on user experiences and satisfaction levels, complementing the quantitative usage statistics.

### 2.4 Analysis techniques

#### 2.4.1 Item analysis

To gauge the quality of exam items, the system employs a process of item analysis, which involves a thorough examination of student responses to individual questions. This comprehensive evaluation helps in assessing the effectiveness and relevance of each question.

#### 2.4.2 Survey analysis

A survey was administered to both faculty and students, consisting of five items related to functionality, interface, support features, ease of use, and satisfaction, using a five-point Likert scale. Survey results were analyzed using descriptive statistics. Responses were visualized in bar charts to highlight the level of satisfaction among users. Statistical analysis (Mann-Whitney $U$ test) was conducted to assess differences in survey responses over time.

#### 2.4.3 Comparison to commercially available software

To identify the strengths and limitations of KEAP, it was compared to a commercially available examination software. This comparison helped to contextualize KEAP's performance and acceptance within the broader landscape of electronic assessment tools.

### 2.5 Design of KEAP software

The software was built using open-source technologies. HTML, JavaScript, and CSS on the front end and PHP programming language on the back end. The system is driven by MySQL database engine and some sensitive information is secured with Advanced Encryption Standard (AES) to prevent unauthorized access to electronic data.

#### 2.5.1 System architecture

Major design considerations included easy data retrieval, easy

database updates, multiple client support, and a minimal administrative features. All data stored is managed using industry-standard data validation tools and triggers. The server application is designed to be as flexible as possible. The server application is designed for flexibility, ensuring that new features do not impact existing functionality or server operability (Table 1, Figs. 2 and 3).

#### 2.5.2 Availability and disaster recovery

The current deployment is in the primary data center and high-availability clusters are setup. In case the primary fails, the application system will be available from the backup server. Regular backups of the KEAP solution are taken and provided by the COD IT team. A nightly backup on both database and application is also available with 6 months of retention.

#### 2.5.3 Security architecture

To deliver secure assessments and reduce security-related risks, new or modified systems are assessed for compliance with information security standards and best practices. The system authentication method requires additional secondary verification via a personalized pin. Application-managed access levels are tailored according to the specific permissions required by different user groups. Multiple logins by the student during the exam is not allowed, and automatic logout is enforced if multiple locations are detected. Audit logs are created to keep the historical record of events such as view, add, edit, and delete actions, which also contain event results, location IP, timestamp, and others.

#### 2.5.4 Maintenance

Application server and system coding are maintained by the Department of Information Technology at the COD, KSAU-HS. Weekly checks are being performed both on the production server and backup server to ensure data integrity and consistency.

## 3 Results

### 3.1 Core functions of the KEAP System

#### 3.1.1 Curriculum mapping and Program Learning Outcomes (PLOs) assessment

For a given program, KEAP enables the insertion of course information, including their Course Learning Outcomes (CLOs). Within the system, educators can input teaching strategies and assessment methods, and align CLOs with the PLOs. Based on this alignment (as depicted in Fig. 1-A), KEAP can swiftly calculate the achievement percentage of each PLO and produce corresponding assessment reports. These reports are utilized in preparation of the annual reports of the program.

#### 3.1.2 Question creation and submission

This user-friendly module enables the creation of multiple-choice questions (MCQs), objective structured practical examinations (OSPE), and short-answer questions. Additionally, the system supports incorporating scenarios and embedding photos or radiographs to enhance the questions. Every question can be mapped to predefined CLOs and given a difficulty level. Item writers have the flexibility to either submit their questions directly to the assessment unit or save them as drafts for subsequent review and refinement (Fig. 1-B).

#### 3.1.3 Question review, editing, and approval

KEAP provides a framework for the technical review of submitted questions, allowing authorized administrators to either accept, reject, or provide feedback and suggestions to the item writer. Additionally, KEAP streamlines the scientific review by allowing content experts to assess and, if necessary, edit, accept, or reject the questions. Once a question receives approval, it's encrypted and automatically transitioned into a secure question bank (Fig. 1-C).

#### 3.1.4 Exam creation and administration

KEAP permits authorized content experts to select exam questions from the question bank and preview the created exam. Once approved, the exam can be set for either paper-based or online delivery. For online examinations, detailed settings can be configured, such as student registration, exam scheduling, answer shuffling, and proctor assignment. During the exam, the assigned proctor initiates the exam at the venue and displays the exam timer. KEAP provides flexibility with an exam management feature that can extend time under special circumstances, in line with the examination and assessment policies at the university. Students can only access their scheduled exam once initiated by the proctor. KEAP also offers real-time monitoring, ensuring each examinee's progress is tracked, verifying complete submissions, and pinpointing student access locations (Fig. 1-D).

#### 3.1.5 Exam grading, result display, and analysis

For online examinations using MCQs, KEAP immediately and automatically grades the test once students submit their answers, subsequently generating an item analysis report. For exams with short-answer

**Table 1**
Assumptions about software and hardware in the design for the KEAP solution.

| Application | Assumptions |
|---|---|
| Both the server environment and client application make the following assumptions about their operational functions; | ■ The system application can be described by the environmental requirements associated to this document.<br>The system application is executing on will have the required resources available as necessary. This entails sufficient memory and permanent storage space, an adequate CPU for the necessary application, and a TCP/IP network connection. |
| The client application makes the following assumptions about its operation environment; | ■ The system application will be access through web browser.<br>The system application will have the necessary access level setup through permission access grants.<br>The system application will track all user activity for audit purposes. |
| The server application makes the following assumptions about its operation environment; | ■ The system application server must utilize Apache as web server. Apache is a open source web server. Apache is focused on high performance, high concurrency and low memory usage. Additional features on top of the web server functionality, like load balancing, caching, access and bandwidth control, and the ability to integrate efficiently with a variety of applications.<br>The system application server will have the necessary databases access through ODBC (Open Database Connectivity).<br>Preferably, the application server will have TCP port 80,443 free for use of the server application. This is the default port for the web server to listen. |
| The database server makes the following assumptions about its operation environment; | ■ The system application is a direct service to each client.<br>The database server is not accessible from external network.<br>Preferably, the database server will have TCP port 3306, free for use of the server application connectivity. |

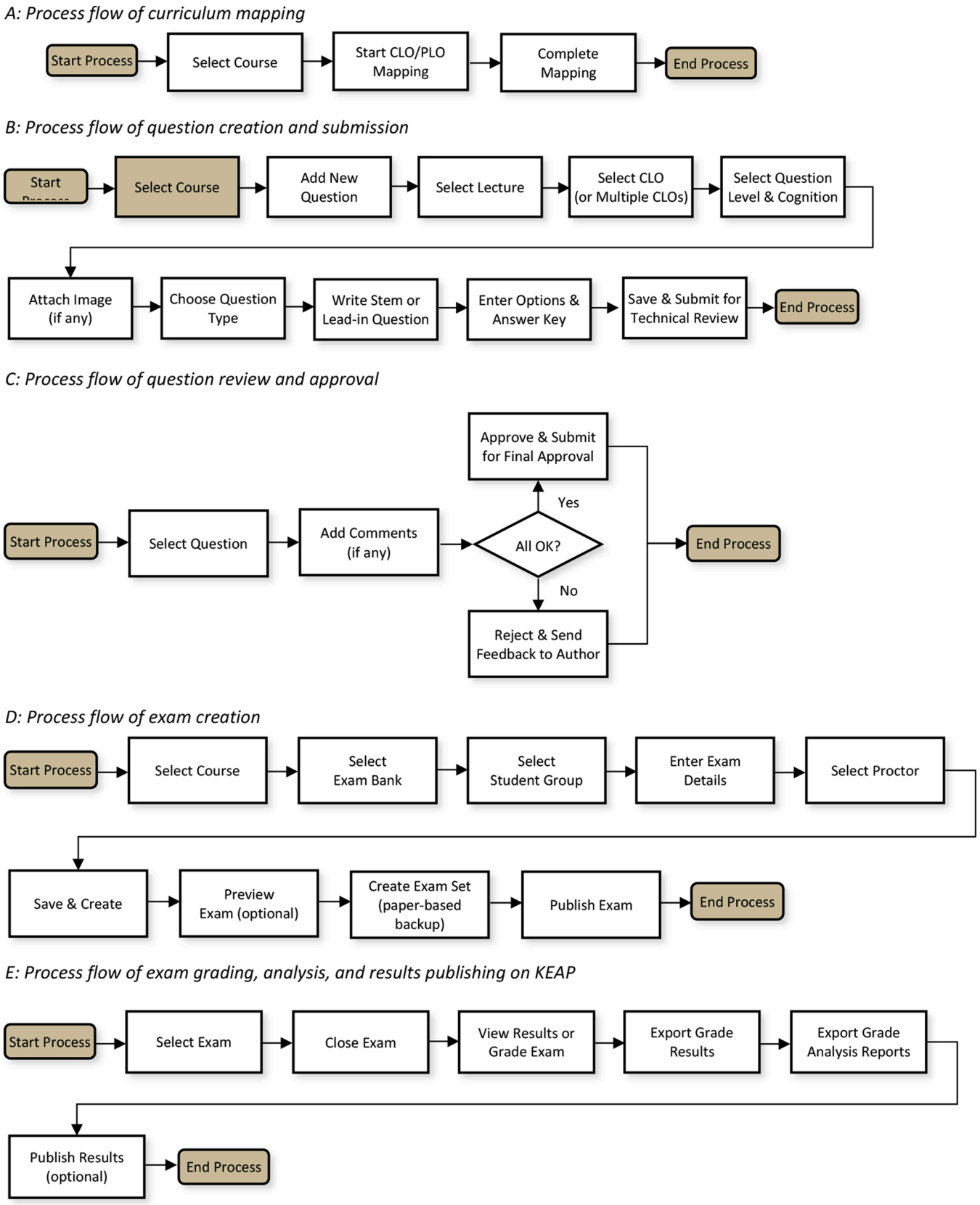



**Fig. 1.** KEAP system's process flows.

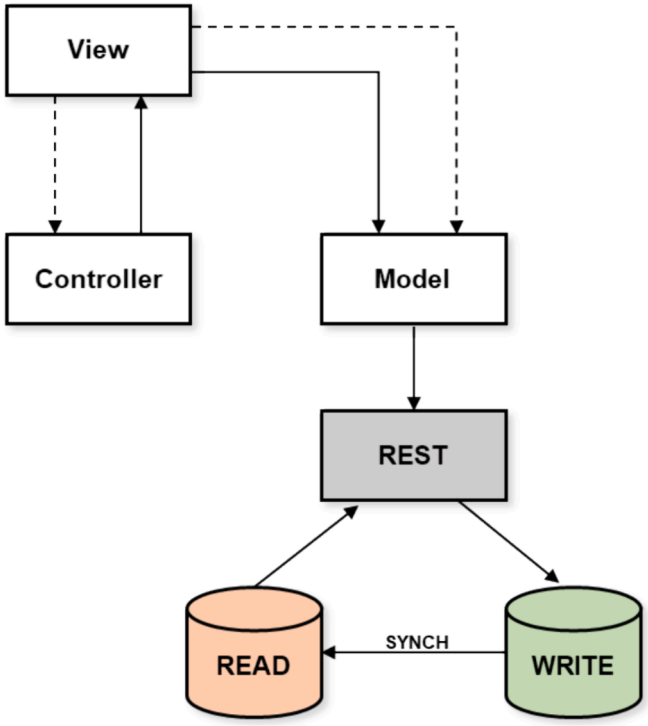



**Fig. 2.** The logical architecture of the solution.

questions, the platform allows faculty members to securely grade each response, offering a dropdown list for scoring and displaying the ideal answer for reference and standardization. Furthermore, KEAP features an option, controllable by the administrator, which enables students to instantly view their results upon submission (Fig. 1-E).

*3.1.6 Other essential features*

In KEAP, the process from question/exam creation to review and final publishing is streamlined, structured, and tightly controlled. This ensures the utmost quality, security, and integrity of the examination materials. Also, KEAP is unique in measuring the level of students' achievement of course and program learning outcomes. This proficiency stems from KEAP's ability to map questions to predefined CLOs, which are in turn pre-aligned with PLOs. KEAP primarily accommodates MCQs and short-answer questions, tailored to accommodate the college's unique requirements.

KEAP provides robust capabilities allowing for test creation from multiple item banks, converting questions into PDF format, or producing printable exams for instances where traditional paper-based exams are necessary or preferred. These capabilities become especially vital as contingency measures during unexpected network disruptions. Additionally, while some commonly used examination software requires students to pre-download the exam file, KEAP eliminates this requirement, allowing students to directly access the exam at the scheduled time without prior download (Xu and Mahenthiran, 2016).

*3.2 Usage statistics*

The statistics available indicate that the KEAP system has been utilized by a total of 53 courses. Throughout this period, around 621 students have utilized the system. Over the span of the last four academic years, KEAP has expanded its question bank by adding over 26,500 questions and has successfully administered a total of 1,255 examinations.

The introduction of the KEAP system has led to a remarkable surge in the number of MCQs received. This growth has been exponential, as evidenced by the following figures: In the academic year 2018–2019, there were 3,596 questions; this figure increased to 5,563 questions in 2019–2020, followed by a further rise to 6,559 questions in both 2020–2021 and 2021–2022, marking the highest point of MCQ submissions.

*3.3 Survey results*

The conducted survey in 2021 revealed that the majority of both faculty members and students expressed satisfaction with the system's functionality. A subsequent survey in 2023, following software improvements, investigated user acceptance of the KEAP system. Results revealed over 90 % satisfaction among students and faculty. Visual representations in the form of bar charts (Fig. 4-A for the faculty and Fig. 4-B for the students) showcased a predominance of "Strongly Agree" or "Agree" responses. Statistical analysis (Mann-Whitney *U* test) assessed differences between 2021 and 2023 responses, indicating no significant variance. Although the descriptive statistics showed that the mean rank scored for the year 2023 was higher on the dependent variables than the year 2021. The results of the Mann-Whitney *U* test indicated that there was no significant difference between the year in which the survey was taken and the responses to the items in the survey. Thus, the study concluded that the KEAP system was well accepted by end users.

## 4 Discussion

A customized, in-house built electronic assessment platform named KEAP was developed at COD, KSAU-HS, Riyadh, Saudi Arabia. It was designed and utilized to fulfill the requirements of curriculum mapping alignment, mapping of learning outcomes, preparing and conducting secured electronic examinations, and generating related reports. The use of KEAP demonstrates an effective integration of technology in education as viewed by the Substitution Augmentation Modification Redefinition (SAMR) model (Puentedura, 2012), which is depicted by its ability to transform and redefine the assessment process while equipping students with the skills of the 21st century.

The positive impact of KEAP on the assessment process can be viewed in different aspects. Firstly, the online submission of MCQs offers

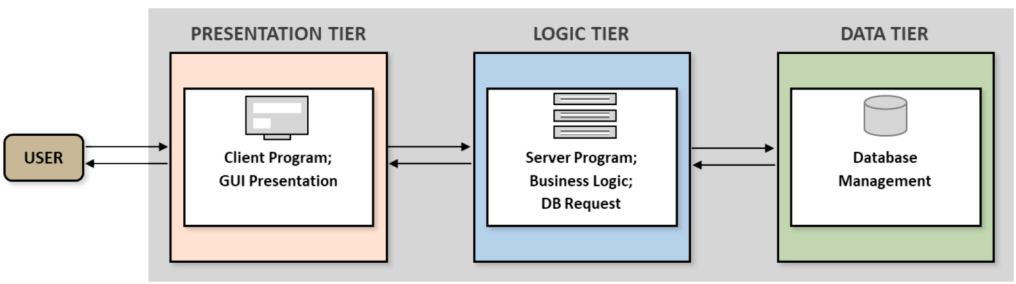
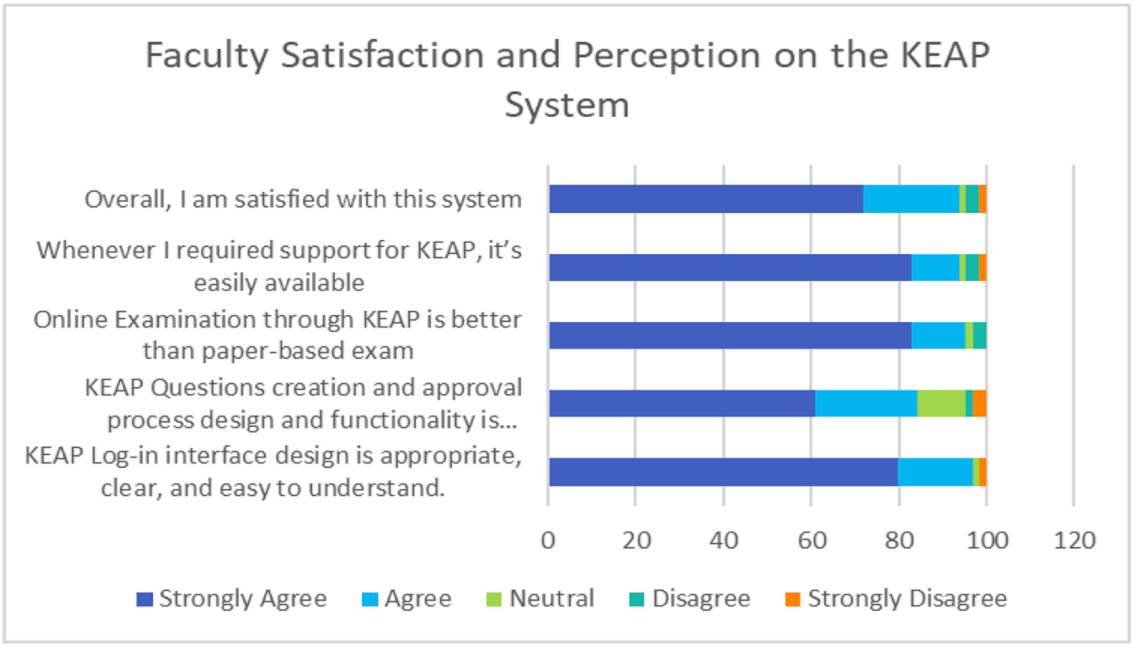



**Fig. 3.** The three-tier architecture used for user-facing applications in KEAP.

*A: Faculty chart*




*B: Students' chart*

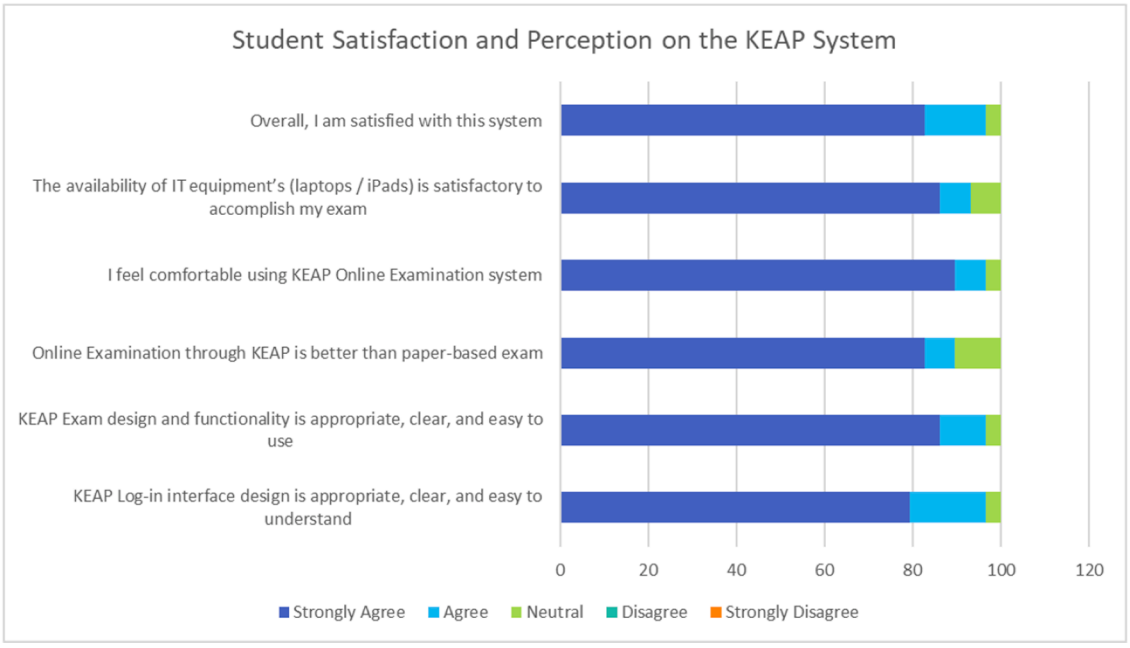



**Fig. 4.** Bar charts depicting the response frequencies of the five items on KEAP satisfaction and perception for faculty and students in 2023.

convenience for faculty members since it allows them to manage their KEAP-related tasks flexibly throughout the day. The questions are typed by faculty members on the KEAP system in a structured form that can be filled easily with all the needed fields, then submitted by one click.

Secondly, the produced exams are highly valid and reliable. At the time of question submission, the KEAP system provides pre-mapped PLOs, CLOs, and learning domains aligned with the submitted question. To ensure the quality of items in the question bank, several quality assurance measures have been implemented. A systematic review process is conducted periodically to identify and remove duplicate questions and update any questions containing outdated information. This review is carried out by subject matter experts and the assessment unit staff. Additionally, psychometric analysis is utilized to evaluate the performance of each question based on student responses. Questions with poor psychometric indices, are flagged for review. These questions are either revised to improve their quality or removed from the question bank if deemed unsuitable. Futhermore, all new questions undergo a rigorous review and approval process before being added to the question bank. KEAP allows the questions to be reviewed by the author and assessment unit staff member to detect and correct any errors while also

showing the history of changes made. KEAP also offers a feature for course coordinators to preview the exam with an interface identical to the students' exam interface, after which they can edit the examination and approve it. These features have resulted in increasing the validity and reliability of exams. Finally, a feedback mechanism has been established where faculty members and students can report issues with specific questions. This feedback is reviewed and acted upon promptly to maintain the integrity of the question bank.

Thirdly, KEAP enhanced exam security. Transitioning to online question submission, exam creation, exam conduction and exam grading has significantly reduced the potential for unauthorized exposure of exam materials. Also, the exam creation process includes an option for shuffling of exam questions and their respective answer choices. Opting for this feature enables the generation of multiple, uniquely shuffled exam sets, minimizing the risk of exam misconduct.

Fourthly, KEAP allowed easy exam creation. Prior to moving to the KEAP system, exam creation was a complex, time consuming and tiring task. Often, it involved printing of all available questions, moving back and forth between pages for question selection, which was a time-consuming task, especially with the need to process more than 6,500 exam questions each academic year at COD. With the availability of KEAP, one can now effortlessly transfer selected questions from the question bank to the exam bank with just a few clicks.

Further, KEAP can generate item analysis and CLOs achievement reports for written examinations instantly. When students submit their exams, KEAP instantly computes the percentage of students who selected each MCQ option, subsequently presenting this data for an item analysis report. Also, KEAP instantly calculates the percentage of achievement of the mapped CLOs and provides course coordinators with CLOs achievement report. This aids them in the preparation of thorough course reports.

The approval and positive feedback for KEAP can be linked to the growing demands of both faculty members and students for digital assessment platforms that offer flexibility and ease of use. Approximately 15 % to 20 % of faculty responses in the KEAP question creation and approval process showed neutrality or strong disagreement (Fig. 4-A), possibly due to the diversity of survey respondents' experiences. Some faculty members had limited exposure to the KEAP system, encountering difficulties that led to a less favorable perception. Others who were accustomed to different systems may have compared KEAP unfavorably. These findings align with similar studies on digital educational platforms, where students generally preferred such platforms (Vaganova et al., 2020, Karibyan and Sabnis, 2021) but contrast with one study indicating that tech-skeptical students remained negative about computer-based testing (Karibyan and Sabnis, 2021). Faculty and students rated KEAP positively for its ease of use, preference over paper-based exams, and satisfaction with support availability.

Nonetheless, it is important to highlight that utilizing KEAP for online exams is confined to the COD premises. This limitation impedes the execution of online examinations from locations outside of KSAU-HS during unforeseen circumstances such as a campus lockdown, inclement weather, or other situations that might prevent students from accessing the campus. Likewise, students' clinical performance assessment data available in the electronic dental health record system is not yet compatible or integrated with KEAP. Consequently, this data is absent from KEAP, thereby preventing the generation of comprehensive assessment reports. However, the potential for integration between KEAP and clinical assessment data in the electronic dental health record system presents itself as an avenue for software improvement. Another limitation of this study is that the evaluation of KEAP's effectiveness has primarily relied on user satisfaction surveys, without incorporating comprehensive measures of reliability, validity, and the impact on student learning outcomes, which we plan to address in future research.

## 5 Conclusions

In conclusion, the design and development of KEAP Electronic Assessment Software is centered on contextual factors in COD, KSAU-HS with a goal to achieve a valid, efficient, standardized, and highly secure assessment process. Moreover, the majority of faculty and student end-users are satisfied with their KEAP experience. The structural layout of KEAP's digital framework, coupled with the positive results of its application, could serve as a blueprint for successfully implementing electronic-based assessments in higher education.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgment

The KEAP Electronic Assessment Software is a property of COD, KSAU-HS that was created through the collaborative efforts of members of various college departments and units. Therefore, the college administration would like to acknowledge the efforts of former and current employees of the Information Technology Department, Academic Affairs Department including the Assessment Unit and the Development and Quality Assurance Unit, who have contributed effectively to the software creation and development.

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