Development and evaluation of a computer based test for anatomy radiographic course examination

R Indrati\(^1\), A H Sulistiyadi\(^1\), S Mulyati\(^1\), S Daryati\(^1\), B Setyawan\(^2\)

\(^1\)Poltekkes Kemenkes Semarang
\(^2\)Universitas Diponegoro

Corresponding author: riniindrati@poltekkes-smg.ac.id

Abstract. The assessment of the anatomical radiography course is to measure the student's ability to identify anatomy on radiographic images. Conventional paper tests have used radiographic images. The limitations of this method are the number of radiographic films and the time-consuming assessment process. This study aimed to develop a computer-based test (CBT) to multiply the instruments, store pictures, and speed up the assessment time. The CBT software can reproduce radiographic images using digital files and a feature to add overlay markers. The placement of markers is done intuitively via a user interface with drag and drop motion recognition. The CBT software also provides features for instrument bank, instrument selection and management for exams, a relational database for examinee identities and exam entries, and automatic grading. CBT development uses the Waterfall Software Life Cycle (SDLC), with black-box testing using the normal value equivalent partition method. The CBT usability test was carried out by measuring user perceptions (5 administrators and 60 students) and comparing them with conventional methods at the 95% significance level. Research time decreased significantly during instrument preparation and the assessment process. User perceptions show that 76% of students and 85% of managers give positive assessments. There is no difference between conventional and CBT assessments with a p-value = 0.067 (p-value > 0.05) so that CBT is very potential to be used as a substitute for conventional paper-based tests in examining anatomical radiography courses.

1. Introduction

Evaluation exams are quantitative measurements of student achievement within the curriculum framework. In the radiograph anatomy course, it aims to measure students' ability to identify anatomical parts on radiographic images. This competency is part of the Radiographic Technic Course in the first year of radiography vocational education. The radiographic anatomy evaluation exam at the Poltekkes Kemenkes Semarang uses a paper-based method. This exam uses a question format in the form of a radiographic film image with a marker button and the answers from the participants are written on the answer sheet. This method is very time consuming since the correction process is performed manually.

The number of test-takers increase every year but the number of instrument and its quality decrease over time. Computer software can replace humans in carrying out data storage and processing procedures in organizations, companies, and universities [1]. So that the implementation of the evaluation exam described above can be converted into a Computer Based Test (CBT) format. A Computer Based Test is a form of examination using computer software that can display questions, store responses from participant tests, perform scoring, and report results [2]. Participants' responses can be in the form of multiple choices or entries that are presented in a software interface [3]. The questions...
displayed on the CBT are stored on a memory device that is managed by a database system. Based on the location and topology, the database can be located on a stand-alone computer, an online computer that connects to a local network or accessed via the internet network [4].

CBT has important advantages compared to paper-based testing, such as ease of instrument replication, easy data storage of test instruments without quality degradation, and instant scoring [5]. Test instruments stored in digital format can also reduce the printing cost of question sheets and answer sheets [6]. From a test participant perspective, the question marking process on CBT is faster than the paper-based test [7]. The scoring process in CBT uses an algorithm so that false-positive or false-negative results due to human errors can be minimized [8]. Computer algorithms can also be added to CBT to replace administrative procedures by exam administrators, such as analyzing test results [9][10].

Research [11] developed CBT for tests of basic computer skills, in the format of multiple-choice questions. The CBT uses a database accessed via the internet (online). CBT was developed with the Visual Basic programming language that runs on the Internet Information Server 4.0 (IIS) platform. The database system used is Microsoft SQL Server 7.0. Yuan-Lung [12] developed CBT with a multiple-choice format with a random display of test questions. This CBT was developed in the ASP (Active Server Pages) language that runs on the Information Server 4.0 (IIS) platform. [Rashad, 2010] developed CBT with a multiple-choice format and text entry (string and numeric). In this system, administrators have the authority to create exams, add questions, edit questions, and delete questions. CBT was developed in the ASP (Active Server Pages) language with DB2 database, which runs on the Windows 2000 Enterprise platform.

The transition process from paper-based to CBT is prone to creating shortcomings. One of the issues is the perception and acceptance of test participants when using CBT. A potential problem that arises is the difficulty of test-takers feeling unfamiliar with the display of questions and difficulties in operating the software [13]. Developing CBT that is dedicated to radiographic anatomy evaluation course is challenging, due to its requirement of marker placement on specific points of the images flexibly. One of the difficulties is that the interface software for general CBT uses questions in sentence format, while the radiographic anatomy evaluation exam requires questions in the form of images with markers (pointers). Each marker has a specific coordinate location in the 2D image at specific anatomical parts.

This research was conducted to implement the Computer Based Test as an instrument for radiographic anatomy evaluation in the Radiographic Technic Course, to test the performance of the software, and to find out the perceptions of the software users. Unlike the conventional CBT’s, CBT for the radiograph anatomy exam provides an intuitive interface to match the type of radiograph anatomy evaluation questions. The question has a multimedia type, with a combination of images and markers placed on a coordinate in the image area. Also, the CBT being developed must be able to run on a stand-alone computer, due to inadequate technological infrastructure.

2. Methods
This research is an experimental study with a one-shot case study design which is divided into two stages, namely software development and measurement of user perceptions (test participants).

2.1. Software development
The development method used is the waterfall method which refers to Pressman (2005) and Hoffer (2008) including system analysis, design, coding (programming), and internal testing.
2.1.1. Requirements analysis. Requirement analysis aims to identify the feature requirements of the CBT. The main requirement of CBT is the process of turning test management procedures into computer algorithms effectively and efficiently. The effectiveness of CBT is measured by the ability of the instrument to measure students’ abilities accurately. The efficiency of the CBT is determined by the speed of correction and the durability of data storage. These two basic needs are translated into features required in CBT.

As a test instrument, CBT is a hub for the activities of the exam administrator and test participants. Administrators have the activity of managing and giving questions, while exam participants give responses, and get scores based on the accuracy of the response. Both of these activities require the division of authority and authentication.

The detailed features of CBT refer to the existing procedures for conducting paper-based tests. The administrator provides questions in the form of radiographic images with anatomical markers that will be referred to in the test questions. Each test question has four answer choices and an answer key. Each question must be answered and given a time limitation to ensure that the number of questions is proportional to the allocated exam time. As a test instrument, the question and answer data from participants must be confidential. Based on these needs, CBT is designed with a login feature that requires a username and password for the user who will access it. After logging in as an administrator, users can form questions by inputting radiographic images, filling in five answer choices, with one correct answer.

After all the questions have been inputted, the user can set the active date for the question and the duration of the exam. Other features available to administrator users are running an automatic correction process, and listing the scores of test participants. The settings feature provides a form for changing username and password.

The second type of user is the test participant type. For participants, CBT provides an identity filling form, an interface for inputting responses, a countdown of the number of questions, and a countdown timer. A large number of items in one picture often confuses the examinees. CBT also requires a warning hint feature to distinguish between questions that have been and have not been worked on. The results of the requirement analysis are stated in the use case. The use cases in Figure 1 and Figure 2 show the features for each type of user.

![Use case for user type administrator](image_url)

**Figure 1.** Use case for user type administrator
2.1.2. **Software design.** After the CBT features were determined, the next stage was the development of the interface design, database design, and question bank development. The use case design is translated into coding language with the Java programming language built in the Eclipse Integrated Development Environment (IDE) and databases built with MySQL. Programming can be broken down into program components or modules (i) login and authentication, (ii) loading questions from the database, (iii) storing responses or answers, (iv) scoring, and (vi) reviewing and analysis of the whole answers.

CBT has an interface to support the placement of markers on questions intuitively. A marker in question in the radiographic CBT is a Java Component (JComponent) entity that supports drag and drops for overlay placement on top of the radiographic image. This feature makes use of the Java programming library which recognizes the initiation of a drag action; and when the event occurs, the property values of the JComponent are the component ID, text label, and initial position coordinates accessed via the DragSource function in the Java programming language. When the drag action is ended (drop), the coordinate value will be changed to the value that is in DropTarget. As a result, CBT users will have the experience of placing question markers intuitively. Figure 3 shows the abstraction of the drag and drop algorithm for marker placement.

![Diagram](image)

**Figure 2.** Use case for user type participant test

**Figure 3.** The abstraction of the drag and drop algorithm for marker placement

2.1.3. **Development of a question bank.** The development of a question bank includes inputting digital radiographic images, filling in the question sentence form, filling in multiple-choice forms, and giving correct answer marks. The digital radiographic image used is the DICOM (Digital Image and Communication in Medicine) format which is converted to JPEG or PNG type.

2.1.4. **Software testing.** Software testing is carried out using Blackbox with partitioning methods to ensure all functions in the application run well. Function tests are applied to components and software functions, both for administrator and participant user types. The test functions of the features for students are: (i) Starting program, (ii) Login, (iii) Loading questions and multiple choices, (iv) answer checking, (v) Changing answers, (vi) Navigation, (vii) Submit exam, (viii) Scoring, and (ix) End Exam or Close Application.
The functional tests for the features for administrator user types are: (i) Starting program, (ii) Login, (iii) Logout, (iv) Choosing Question Packages, (v) Deleting Question Packages, (vi) Changing Question Packages, (vii) Adding Image Radiograph, (viii) Deleting Image Radiograph, (ix) Adding Button, (x) Deleting Button, (xi) Filling Problem Form, (xii) Filling Multiple Choice Form, (xiii) marking a correct answer, (xiv) Filling in the correct answer form, (xv) Changing the Active Status for Questions, (xvi) Choosing the date of activation of the questions, (xvii) Setting the Exam Duration, (xviii) Showing reviews, (xix) Changing admin username, (xx) Changing Admin Password, (xxi) Close the application.

2.1.5. **Measuring user perception.** The performance test is done by comparing the results of the assessment with CBT and conventional methods as well as with the performance appraisal by the respondents. The test was carried out by 60 second-year students who had the competence in evaluating radiograph anatomy and five lecturers who taught Radiographic Engineering courses. The analysis was carried out by functional test and paired t-test to determine the difference between the results of the assessment with CBT and with conventional methods with a significance level of 95%.

3. **Results and discussion**

3.1 **Results**

3.1.1. **Software interface and feature.** After going through the stages of system analysis, design, and coding (programming), a CBT is developed under the following features: (i) Login administrator and participant login, (ii) Entry questions, (iii) Question bank, (iv) Setting timing of the exam, (v) Setting the active date of the question, (vi) Setting username and password, (vii) Test running, (viii) Correction of answers, and (ix) Storage of exam scores. The functions displayed on the CBT application during operation are shown in the following pictures.
3.1.2 Software testing using blackbox method. In this study, the software testing technique used was BlackBox testing with the equivalent partitioning method. The Equivalence Partitions method is a Black Box testing method that breaks or divides the input domain of the program into data classes so that a Test Case can be obtained. The design of Test Case Equivalence Partitions is based on input conditions that describe a set of states that are valid or not. An input condition can be a numeric value, a range of values, a set of related values, or a Boolean condition. Figure 5 is an example of the results of the equivalence partition for the form on the question entry page.

![Figure 4.e. Test running equipped with a counting timer](image1)

![Figure 4.f. Auto Scoring](image2)

![Figure 4.g. Score management](image3)

### Figure 5. The results of the equivalence partition for the form on the question entry page

3.1.3 Accuracy test and difference test. The automatic grading accuracy shows the test result at 100%. Different tests for comparing the assessment method with the CBT application with the conventional method (paper-based test) are shown in Table 1.

| Variable | p-value |
|----------|---------|
| CBT application | 0.067 |
| Conventional method (paper based test) | |
The results of the t-test showed no difference between the assessment of the CBT application and the conventional assessment (paper-based test) with p-value = 0.067 (p-value > 0.05). The results of this test indicate that the test method with the CBT application can be used as a new method of replacing the assessment with a paper-based test with a faster result.

3.1.4 User perception. Performance assessment of CBT by users has shown positive results (Table 2).

**Table 2. Results of user perceptions measurement (students)**

| No | Score Point | Yes  | No  |
|----|-------------|------|-----|
| 1  | Navigation Convenience | | |
| a. | The application interface is easy to use | 86% | 16% |
| b. | The available buttons help the operation of the application | 82% | 18% |
| c. | The information on the interface is very informative | 76% | 24% |
| 2  | Content of cognition | | |
| a. | Instructions provided in the interface help the operation of the application | 66% | 34% |
| b. | Button function is easily operated | 82% | 18% |
| c. | The description on the interface is easy to understand | 76% | 24% |
| 3  | Information presentation | | |
| a. | Information on how to operate the apps is available | 11% | 89% |
| b. | There is information to see the questions, the time available, and the scores obtained | 82% | 18% |
| 4  | Media integration | | |
| a. | Multimedia integration of text and images are available | 100% | 0% |
| b. | Integration of multimedia audio and video is available | 0% | 100% |
| c. | The purpose of the application is conveyed well through multimedia | 84% | 18% |
| d. | Multimedia integration makes the apps more attractive | 84% | 13% |
| 5  | Artistic and aesthetic | | |
| a. | The interface is attractive and informative | 84% | 16% |
| b. | Layout design displays both questions, answers, time, next, prev, and scoring meet artistic and aesthetic values | 84% | 16% |
| c. | Good radiograph image display | 89% | 11% |
| 6  | Overall function | | |
| a. | The application is easy to operate | 89% | 11% |
| b. | The application helps in exam time management | 87% | 13% |
| c. | The application help students to find out the exam score quickly | 89% | 11% |
### Table 3. Results of user perceptions measurement (lecturer/administrator)

| No | Score Point | Yes | No |
|----|-------------|-----|----|
| 1  | Navigation Convenience | | |
|    | a. The application interface is easy to use | 100% | 0% |
|    | b. The available buttons help the operation of the application | 100% | 0% |
|    | c. The information on the interface is very informative | 100% | 0% |
| 2  | Content of cognition | | |
|    | a. Instructions provided in the interface help the operation of the application | 80% | 20% |
|    | b. Button function is easily operated | 100% | 0% |
|    | c. The description on the interface is easy to understand | 100% | 0% |
| 3  | Information presentation | | |
|    | a. Information on how to operate the apps is available | 0% | 100% |
|    | b. There is information on the list of available question packages, exam arrangements, and the scores obtained | 100% | 0% |
|    | c. Information to view questions and answer keys are available | 100% | 0% |
|    | d. Information about correct and wrong answers | 100% | 0% |
| 4  | Media integration | | |
|    | a. Multimedia integration of text and images are available | 100% | 0% |
|    | b. Integration of multimedia audio and video is available | 0% | 100% |
|    | c. The purpose of the application is conveyed well through multimedia | 80% | 20% |
|    | d. Multimedia integration makes the apps more attractive | 80% | 20% |
| 5  | Artistic and aesthetic | | |
|    | a. The interface is attractive and informative | 80% | 20% |
|    | b. Layout design displays both questions, answers, time, next, prev, and scoring meet artistic and aesthetic values | 80% | 20% |
|    | c. Good radiograph image display | 100% | 0% |
| 6  | Overall function | | |
|    | a. The application is easy to operate | 100% | 0% |
|    | b. The application helps in exam management | 100% | 0% |
|    | c. The application can help make exam scoring quickly | 100% | 0% |
|    | d. The application has adequate security features | 80% | 20% |

#### 3.2 Discussion

The background of CBT for radiographic anatomy evaluation development was the results of the needs assessment that conventional methods were inefficient as it still used analog film (radiograph). There is a particularly urgent need for new methods that could be more efficient and works effectively. The use of CBT is expected to reduce the time for exams significantly which normally takes several days if conventional methods were used.
Following Smaldino [14], which states that CBT has many advantages, including low cost (for long-term use), deliver results quickly, flexible time and test procedures, test results are more accurate because they are checked by a computer, and more objective than tests corrected by humans, also a more practical storage for test materials and test results. This rationale becomes a system requirement which is the first stage of making software.

The CBT application is made to work with offline systems or unconnected to the network (stand-alone) due to the consideration of infrastructure readiness and limited research time. There are advantages and disadvantages to using a stand-alone system. Being designed to work in offline mode, the CBT application is considered to be more compatible with various characteristics of computers and networks. While the downside of this system is that the lecturer or administrator must do the settings test and check the score one by one on each computer. However, compared with the time required for conventional examination management, these weaknesses are still much more efficient.

CBT allows lecturers to manage the exam, including selecting exam packages, filling in questions along with answer keys, storing and deleting exam scores, setting exam duration, activating exam questions, or changing usernames and passwords. The CBT itself is designed to be dynamic. Questions, answer choices, and answer keys can be changed according to the required competencies. This software can be used for examinations for other subjects in the form of image identification and multiple choice types questions.

This CBT software system allows students to fill in the identity of the examinees, select and cancel answers, move to the next question or return to the previous one, obtain information on remaining exam time, collect final answers, and the scores obtained. These features support the students' fluency in working on the questions. The CBT display is designed to be user-friendly and adaptable, with aesthetics graphics in mind. This can be seen from more than 80% of users who stated that this application is easy to use, and beautiful or aesthetically attractive. It is expected that test takers do not get stress due to a confusing display.

The confidentiality of exam questions in CBT can be maintained by several security methods. The first method of security is the use of a username and password which is known only to the lecturer and or administrator. Another security system is setting the active date of the question so that questions can only be opened at a certain time according to software does not require an internet connection, internet access can be turned off during exams so that students do not misconduct the chance to cheat.

Reliability test results showed that there were no conclusions from the results of research with CBT and conventional methods. This might happen due to the similar workflow between CBT applications and conventional methods which are not different. Also, the digital image display in the CBT has the same or even better quality than the analog image used in conventional methods so that there are no errors in answering due to the unclear anatomical structure of the radiograph. Also, the quality of the digital image will not be damaged, such as the analog image, which if it is used more frequently, will suffer more physical damage.

Considering its advantages and disadvantages, the CBT application can be used as an instrument for the Radiograph Anatomy Evaluation Examination in the Radiographic Engineering Course in the Department of Radiodiagnostic Engineering and Radiotherapy, the Semarang Health Polytechnic of the Ministry of Health as well as in other radiograph education streams. Development is needed to improve this computer-based software, by adding a user manual feature, so that the lecturer or exam supervisor does not need to explain every time before the exam starts.

4. Conclusion

The development of CBT was completed with the Waterfall Software Life Cycle (SDLC), with black-box testing using the normal value equivalent partition method. Usability testing of CBT was done by measuring user perceptions (5 administrators and 60 students, with radiographic anatomical evaluation competencies) at the Health Polytechnic of Semarang. Work time measurements showed a significant reduction during instrument preparation and scoring processes. Meanwhile, the measurement of user perception showed that 76% of students and 85% of administrators gave positive ratings. The accuracy
test for CBT shows 100% accurate. There was no difference between the conventional assessment (paper-based test) and the automatic assessment of CBT (p-value = 0.067). CBT provides faster results than the paper-based test assessment. CBT has the potential to be used as a substitute for conventional paper-based tests in anatomical radiography examination courses.

References
[1] Fagbola M, Baale, Adebisi and Oke A 2013 *International Journal Of Scientific & Technology Research* 28 336-342
[2] Whittington D, Bull J, Danson M 2000 *Web-Based Assessment: Two UK Initiatives. The Sixth Australian World Wide Web Conference* Rihga Colonial Club Resort Cairns 12-17 June
[3] Taylor A R 2005 *A Future in the Process of Arrival: Using Computer Technologies for the Assessment of Student Learning* Kelowna British Columbia Society for the Advancement of Excellence in education
[4] Newhouse C P 2013 *Research and Practice in Technology Enhanced Learning* 8 3 431-447
[5] Adegbiya M V, Fakomogbon F O, Daramola 2012 *British Journal of Science* 31 1 59-66
[6] Fagbola T M, Adigun A, Oke A 2013 *International Journal of Scientific & Technology Research* 28 336-342
[7] Bodmann S, Robinson D 2004 *Journal of Educational Computing Research* 31 1 51-60
[8] Adewale O A, Ajadi T, Inegbedion J 2011 *Perception of learners on Electronic Examination in Open and Distance Learning Institutions: A Case Study of the National Open University of Nigeria.* [23] Akunyili, D. (2010). ICT and e-government in Nigeria: Opportunities and Challenges
[9] Jamila M, Tariq S 2012 *The Turkish Online Journal of Educational Technology* 11 4 371-381
[10] Osang F 2012 *International Journal of Information and Education Technology* 2 4 304-307
[11] Zhenming Z, Liang Z, Guohua Z 2003 *33rd ASEE/IEEE Frontiers in Education Conference* S3F-7-S3F-10
[12] Yuan-Lung Y, Tsung-Chih H, Li Chuan C 2005 *East sea management comment* 7 1 109-120
[13] Alabi A T, Issa A, Oyekunle A 2012 *International Journal of Learning & Development* 2 3 68-80
[14] Smaldino Paul 2018 *Evolutionary Behavioral Sciences* 12 173-176