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Securing Logins in Electronic Examination Systems for Tertiary Institutions Using Quick Response Code (QR) Technology and Multiple Hashing Algorithms

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This work is aimed at adding an extra layer of security to the login process of an electronic examination system as security has been identified as one of the critical success factors in the management of such exams. It proposes to secure the login process of an e-exam system through authentication and encryption to control access and avoid impersonation. A model of the e-exam system with Quick Response (QR) code generation capability was designed where a student's matriculation number is accepted as input which is then converted into a two-dimensional bar code using a QR generator. Outputs from the QR code generator are then secured by encryption using MD5 and SHA-224 encryption algorithms. MD5 algorithm produces a 32-bit hash value which is further encrypted using SHA-224 that produces a resulting 56-bit hash value that is then saved in the password column of the user table in the database. This research resulted in a secure and web-based electronic examination authentication system implemented and tested on a client-server architecture. Performance evaluation of the developed system revealed that it is fast and effective, capable of authenticating students in an average of 0.624 seconds when the smartphone flashlight is off, and 0.318 seconds with flashlight turned on and consequently, resistant to brute force

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attacks. This paper fulfils an identified need to develop an electronic exam system that not only secures the question bank but equally ensures the security of the login process as well as the login details using a combination of two security techniques.

Keywords: Algorithm; authentication; electronic examination; encryption; quick response code; security.

1. INTRODUCTION

Examination is one of the best methods of measuring or assessing students' knowledge, and there are two ways in which examinations are conducted, viz: traditional and electronic examinations. The pen and paper method of writing examination is the same as the traditional or conventional means. All forms of examinations serve as first, a feedback mechanism for the examiner to ascertain the level of knowledge acquired and also a measure of knowledge retention by the student. Any misconduct or irregularity distorts this feedback mechanism and gives a false outcome of the learning process and has negative consequences [1]. According to Ajinaja [2], electronic examination is the use of computers that are connected to the internet or intranet to conduct or administer examinations.

Most higher institutions in Nigeria (such as Ladoke Akintola University of Technology, Ogbomoso; Federal University of Technology, Minna; University of Ibadan, University of Ilorin, amongst others in Nigeria), and other examination bodies (such as the Joint Admission and Matriculation Board, which have over one million candidates every year), have adopted the use of electronic examination method because it is cost-saving, quicker, easier and convenient to administer and use. Also, the electronic examination has been more effective than the traditional method because it eliminates leakages of examination questions, bribe-taking by supervisors, and demand of gratification by lecturers or examiners. However, with the introduction of e-exams, institutions still wrestle with security concerns such as impersonation if authentication is poorly done.

To realize these attendant benefits of e-exams, security requirements must be satisfied and preserved. Hence, this paper attempted to ensure students' authentication in an e-examination setting guided by the following objectives:

i. design of a model of the e-exam system with qr-code generation capability
ii. implementation of encryption algorithms for double encryption of generated password from (i) using MD5 and SHA-224
iii. evaluation of the developed system

2. LITERATURE REVIEW

2.1 Quick Response (QR) Code

QR code (abbreviated from Quick Response code) is a type of two-dimensional barcode first designed in 1994 by Masahiro Hara from the Japanese company Denso Wave for the automotive industry in Japan. A barcode is a machine-readable optical label that contains information about the item to which it is attached. In practice, QR codes often contain data for a locator, identifier, or tracker that points to a website or application. A QR code uses four standardized encoding modes (numeric, alphanumeric, byte/binary, and kanji) to store data efficiently; extensions may also be used. The Quick Response system became popular outside the automotive industry due to its fast readability and greater storage capacity compared to standard UPC barcodes. Applications include product tracking, item identification, time tracking, document management, and general marketing.

A QR code consists of black squares arranged in a square grid on a white background, which can be read by an imaging device such as a camera, and processed using *Reed–Solomon error correction* until the image can be appropriately interpreted. The required data is then extracted from patterns that are present in both horizontal and vertical components of the image. QR codes may be used to display text to the user, to open a webpage on the user's device, to add a vCard contact to the user's device, to open a Uniform Resource Identifier (URI), to connect to a wireless network, or to compose an email or text message. There are numerous QR code generators available as software or as online tools that are either free, or require a paid subscription. The QR code has become one of the most-used types of two-dimensional code.

QR codes can be used to log into websites: a QR code is shown on the login page on a computer screen, and when a registered user scans it with a verified smartphone, such will automatically be logged in. Authentication is performed by the smartphone which contacts the server, it can be used to verify the authenticity of a software user. A QR code is designed in such a way that it is detected by a 2-dimensional digital image sensor and then digitally analyzed by a programmed processor. The processor locates the three distinctive squares at the corners of the QR code image, using a smaller square (or multiple squares) near the fourth corner to normalize the image for size, orientation, and angle of viewing. The small dots throughout the QR code are then converted to binary numbers and validated with an error-correcting algorithm. The amount of data that can be stored in the QR code symbol depends on the datatype (mode, or input character set), version (1, ..., 40, indicating the overall dimensions of the symbol, i.e. 4 × version number + 17 dots on each side), and error correction level. The maximum storage capacities occur for version 40 and error correction level L (low), denoted by 40-L. The Fig. 1 below shows the QR code structure.

QR code has a powerful error-correction mechanism that is implemented by Reed-Solomon algorithm. This allows a QR Code symbol to be read even if it is impaired or damaged. There are four levels of available error correction that QR code possesses: L, M, Q and H with L being the lowest- 7%, M has 15%, Q-25%, and H being the highest- 30% error correction level.

2.2 Hashing Algorithms

2.2.1 MD5

In 1991 Rivest developed MD5 (Message Digest) as an upgrade to MD4. It is different from MD4 in that it processes each block in 4 more complex rounds, which are different than the 3 round that MD3 uses. It is also slower than MD4 but much more secure. The algorithm is defined in RFC1321 and is as follows:

i. Pad message so its length plus 448 is divisible by 512.
ii. Append a 64-bit value to the end of the message.
iii. Initialize the 4-word (128-bit) buffer (A,B,C,D).
iv. Process the message in 16-word (512-bit) blocks.
v. Output hash value is the final buffer value.

2.2.2 SHA 224

SHA was introduced by NIST & NSA in 1993 and was revised in 1995 after some concerns, which were never released, were found by NIST. It produces a 160-bit digest. Today, it is in use as the standard for the DSA signature scheme. It is based on the MD5 algorithm and was designed to replace it. The algorithm is as follows;

i. pad message so its length is a multiple of 512 bits.
ii. initialize the 5-word (160-bit) buffer (A,B,C,D,E).
iii. process the message in 16-word (512-bit) chunks.
iv. expand the 16 words into 80 words by mixing and shifting.
v. using 4 rounds of 20 bit operations each on the chunk, buffer.
vi. add the output to the input to form the new buffer value.
vii. output hash value is the final buffer value.

2.3 Related Works

There are various works on electronic examination systems, and a few of these works are highlighted in this section.

Yunus and Hussein [4] submitted that the problems associated with the conduct of electronic examination for testing the abilities of university students or candidates includes security issues, poor integrity of examination questions which is due to examination questions passing through many hands, and lack of resumption capability when power, network or physical computer’s component fails. They also noted that choice randomization within each question must be performed to ensure security, robustness against cheat attempts during examination process and impersonation in the examination hall, as well as conspiracy and collaboration of security agents and officials to compromise the integrity of the examination.

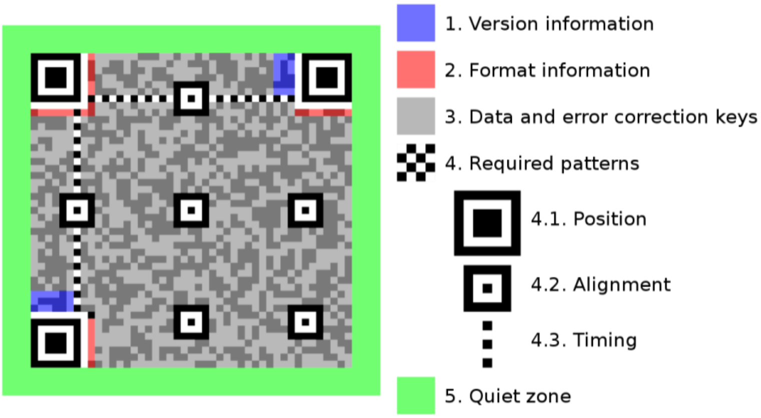


Fig. 1. QR Code Structure [3]

Rashad, Kandil, Hassan and Zaher [5] also developed an examination management system that is capable of supporting an institution's faculty, student and administrator roles in the examination process. The system supports different question types such as; Yes/No, multiple choice single answer, multiple choice multiple answers, fill in the gap, numeric answers and essay answers. Also, examinations are automatically marked on submission of answers and reports/results are produces.

Similarly, Ayo, Akinyemi, Adebiyi and Ekong [6] proposed a model for e-Examination in Nigeria where all applicants are subjected to online entrance examination as a way of curbing the irregularities as proposed by the Joint Admissions Matriculation Board (JAMB), the body saddled with the responsibility of conducting entrance examinations into all the Nigerian universities. This model was designed and tested in Covenant University in Nigeria. The study revealed that the system has the potentials to eliminate some of the problems associated with the traditional methods of examination such as impersonation and other forms of examination malpractices.

Based on the development of e-learning in the only Open University in Nigeria, Ipaye (2009) discusses the process of establishing e-learning environment. A web application was designed and developed, where tests in multiple choice formats will be taken online and graded immediately. The web application runs on the Microsoft.net framework, uses the ASP.NET web server, C# as the intermediate language, ADO.NET to interact with the relational database and Microsoft SQL server as the relational database.

Patil, Bhandari and Kasar [7] employed a methodology for creating QR codes by which the users supplied data is encoded into the QR code image that is captured through java-enabled mobile camera device and then information is retrieved through the decoding process. The system is android-based and designed to authenticate students in a virtual word examination setting.

The use of QR code technology was also proposed by Adeniyi, Amusan, Olagunju and Ogundokun [8] as an effective tool for authenticating students' identity card before they are granted access into either an examination centre or even lecture rooms.

Adebayo and Abdulhamid in [9] designed and implemented an e-exam system for Nigerian universities. The focus here was on the integrity of result and security of the questions both in storage form and transit, hence, data encryption was used.

Ismail and Soye [10] developed a computer based test (CBT) system with biometric fingerprint authentication capabilities which is also able to capture picture, encrypt and decrypt examination questions to reduce the problem of human interference and question leakages among others.

Furthermore as case study, the analysis of the existing electronic examination system in Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, revealed that the institution uses intranet setup in the electronic examination centers containing hundreds of computers. Authentication is done by scanning the students' fingerprints in order to generate their login details.

Arising from the review of existing e-examination systems, it is observed that encryption algorithms are used to encrypt exam questions during transmission or in storage in the database, that is, security emphasis is mostly placed on the content of the e-exam systems and less to securing the login credentials of students. The proposed system is therefore different as it employs the use of QR code technology to authenticate alongside multiple algorithms to save users' login details.

3. METHODOLOGY

The research method of realizing the ultimate aim of this work includes system model design and implementation in form of software application development which is as presented in this section. The model of the secure e-examination system is as shown in Fig. 2.

Fig. 2. shows the model of the proposed QR code generation and password encryption. Student details are supplied as inputs during addition/registration of students. The matriculation numbers are used to generate QR code which are used during authentication to generate login details for students, and passwords supplied are also encrypted using MD5 and SHA-224 algorithms, and saved in the password column of the user database table.

The QR code on the examination slips are scanned and login details are generated and printed. The index page of the system provides a login page, where users supplies the login details (matriculation number and passwords). The passwords are then first encrypted using MD5 algorithm, and the resulting hashed value is further encrypted using SHA-224 algorithm. The hashed value is then compared with the hashed password in the password column of the user database table. If the values are equal, then access is granted into the system, else, an error is flagged. After a successful log in, users are presented with different dashboards, based on their roles in the system. It is the role of the administrator to add, edit and delete courses; add questions to courses; create, edit, start and stop examinations; add, edit, delete and authenticate users. Students, on the other hand, can only start, resume and submit examinations, and view examination results.

3.1 Procedure for Generating QR Code

i. The administrator collects students bio-data such as surname, other names, matriculation number, department, mobile number, email address, etc.
ii. The student data are used to create profile for each student.
iii. The matriculation number is fed as input to the QR code generator.
iv. QR generator generates a unique QR code for each matriculation number, and is displayed alongside other information on the details page.

3.2 Procedure for MD5 and SHA-224 Encryption

i. An 8 characters long word is supplied as input.
ii. The input is first hashed using the MD5 encryption algorithm, and a resulting 32-bit word is produced.
iii. The 32-bit word produced from (ii) above is then further hashed using SHA-224 encryption algorithm, and a 56- bit word is produced and saved in the database.

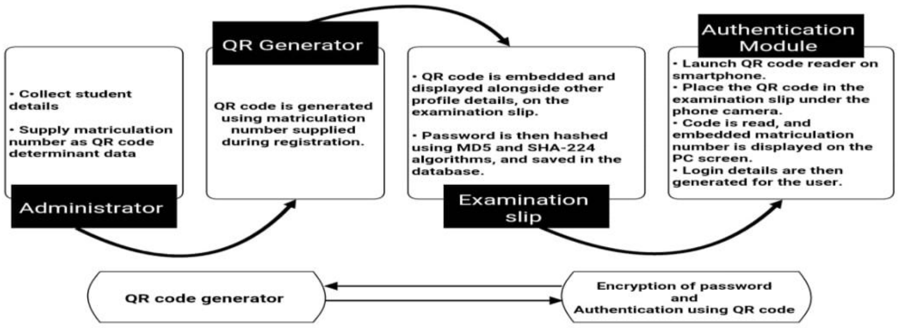

QR Generator
Authentication Module
• Collect student details
• Supply matriculation number as QR code determinant data
QR code is generated using matriculation number supplied during registration.
• QR code is embedded and displayed alongside other profile details, on the examination slip.
• Password is then hashed using MD5 and SHA-224 algorithms, and saved in the database.
• Launch QR code reader on smartphone.
• Place the QR code in the examination slip under the phone camera.
• Code is read, and embedded matriculation number is displayed on the PC screen.
• Login details are then generated for the user.
Administrator
Examination slip
QR code generator
Encryption of password and Authentication using QR code

Fig. 2. Proposed QR Code Generation and Password Encryption Model

4. RESULTS AND DISCUSSION

The secured electronic examination authentication system was implemented and tested on a client-server architecture using web programming and various markup languages such as PHP, CSS, HTML, JavaScript, AJAX, JQuery and SQL; and a local XAMPP server. These languages have been used because they are platform independent, and can be deployed in any computer architecture. PHP is a server side scripting language that is used to make dynamic and interactive web pages; CSS describes how elements should be displayed on the web page; HTML is a markup language for creating web pages; JavaScript and JQuery are used to program the behavior of web pages; AJAX is used to read data from a web server after the web page has loaded, and also to send data to a web server in the background; while SQL is a standard language used with PHP, to store, manipulate and retrieve data from the database.

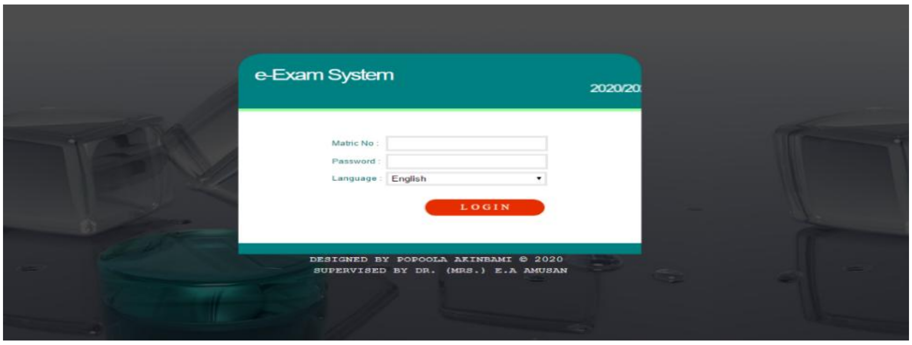
This section presents the output of the developed electronic examination system in forms of application interface, administrator interface/homepage, student homepage, user registration page, details and examination slip page, administrator authentication page, encryption algorithm output and database Table showing encrypted passwords.

Fig. 3 is the index, as well as login page. All users of the application (including the administrator) have to supply their valid User ID/Matriculation number and password, in order to gain access into the software. The system administrator have their passwords, while students' passwords can only be generated by a logged in administrator, through the application's authentication module.

Fig. 4 shows the administrator homepage, where all examination information are displayed. The administrator have access to all courses, examinations, questions, users, and information on active or finished examinations, as well as each user's scores.

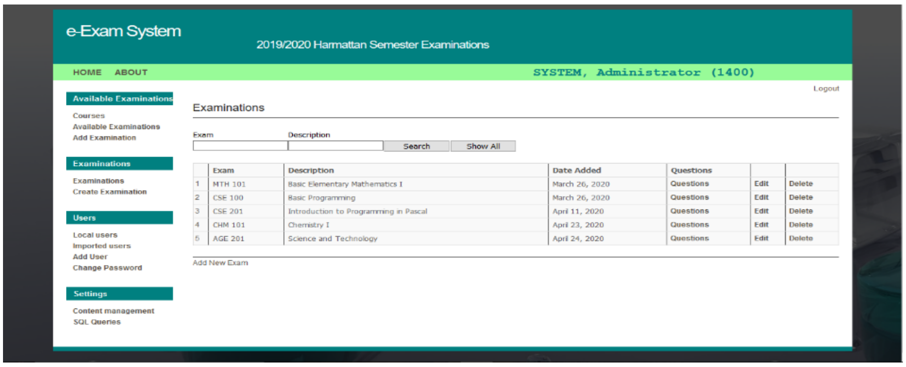
The student's dashboard as depicted in Fig. 5 is where each student user have access to unattempt and completed examinations. Users can start or continue active examinations, or view results of completed examinations on this page.

The examination list page as shown in Fig. 6 shows the semester, session, course code, course title, set of questions for each course, date added and action buttons.



DESIGNED BY POPOOLA AKINBAMI © 2020
SUPERVISED BY DR. (MRS.) E.A AMUSAN

Fig. 3. Index Page



2019/2020 Harmattan Semester Examinations

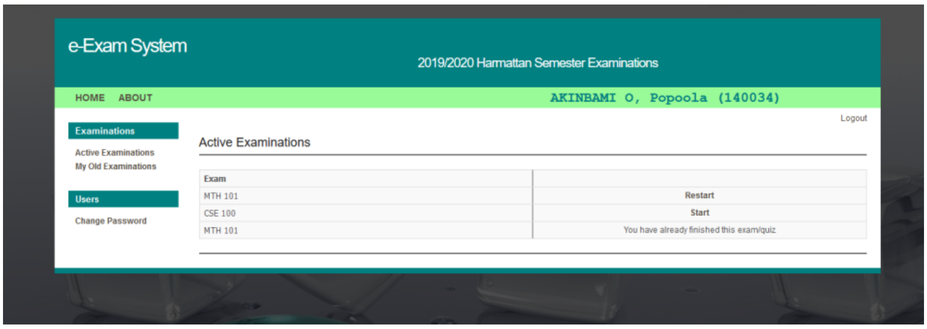
SYSTEM, Administrator (1400)

Examinations

Exam:
Description:

	Exam	Description	Date Added	Questions		
1	MTH 101	Basic Elementary Mathematics I	March 26, 2020	Questions	Edit	Delete
2	CSE 100	Basic Programming	March 26, 2020	Questions	Edit	Delete
3	CSE 201	Introduction to Programming in Pascal	April 11, 2020	Questions	Edit	Delete
4	CHM 101	Chemistry I	April 23, 2020	Questions	Edit	Delete
5	AGE 201	Science and Technology	April 24, 2020	Questions	Edit	Delete

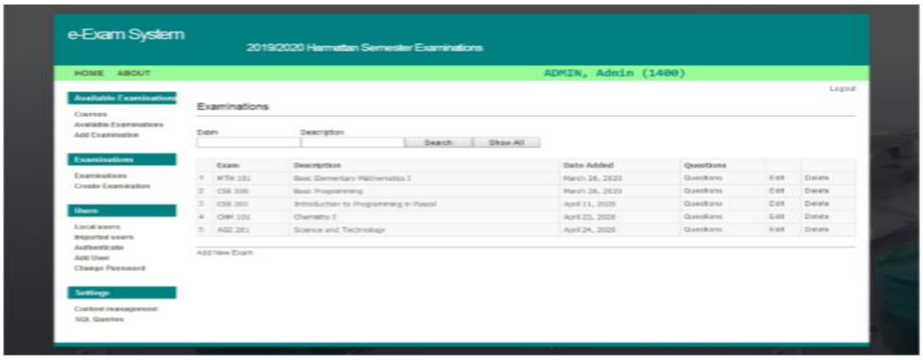
Fig. 4. Administrator Dashboard



Active Examinations

Exam	
MTH 101	Restart
CSE 100	Start
MTH 101	You have already finished this exam/quiz

Fig. 5. Student's Dashboard

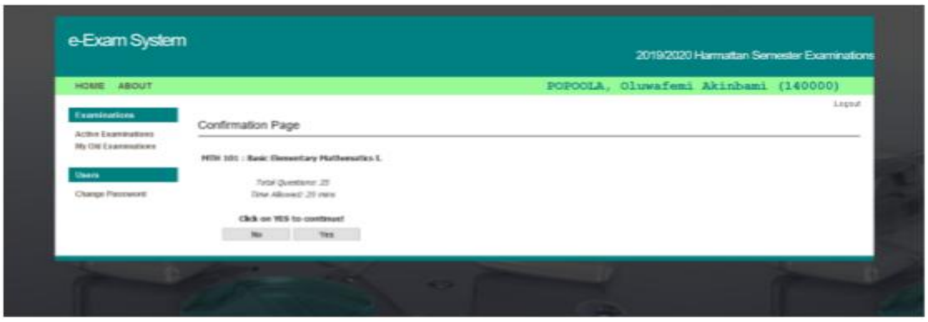


Examinations

Exam
Description

	Exam	Description	Date Added	Questions		
1	MTH 101	Basic Elementary Mathematics I	March 26, 2020	Questions	Edit	Delete
2	CSE 100	Basic Programming	March 26, 2020	Questions	Edit	Delete
3	CSE 201	Introduction to Programming in Pascal	April 11, 2020	Questions	Edit	Delete
4	CHM 101	Chemistry I	April 23, 2020	Questions	Edit	Delete
5	AGE 201	Science and Technology	April 24, 2020	Questions	Edit	Delete

Fig. 6. Examination List Page



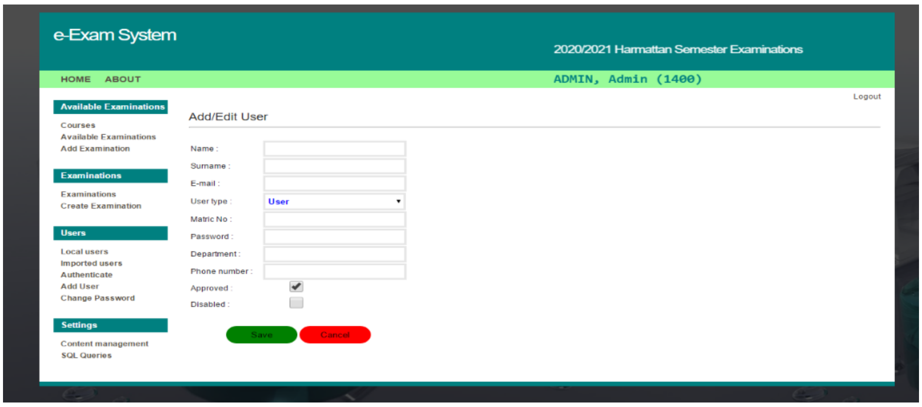
Confirmation Page

MTH 101 : Basic Elementary Mathematics I

Total Questions: 25
Time Allowed: 25 mins

Click on YES to continue!

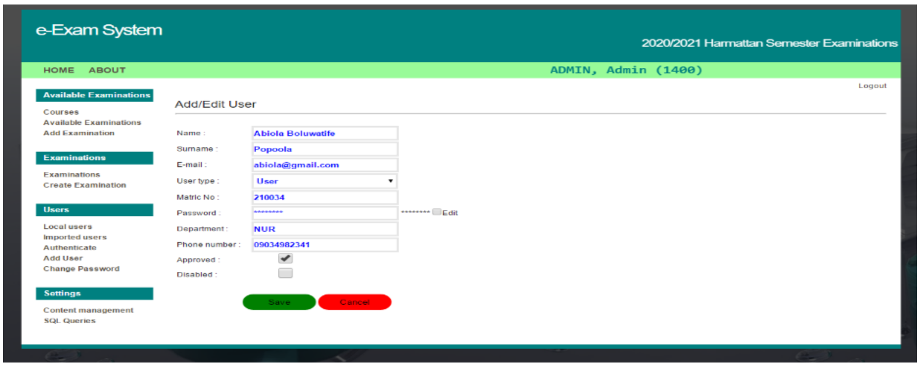
Fig. 7. Student's Examination Start Page



Add/Edit User

Name :
Surname :
E-mail :
User type : User
Matric No :
Password :
Department :
Phone number :
Approved : ☑
Disabled : □

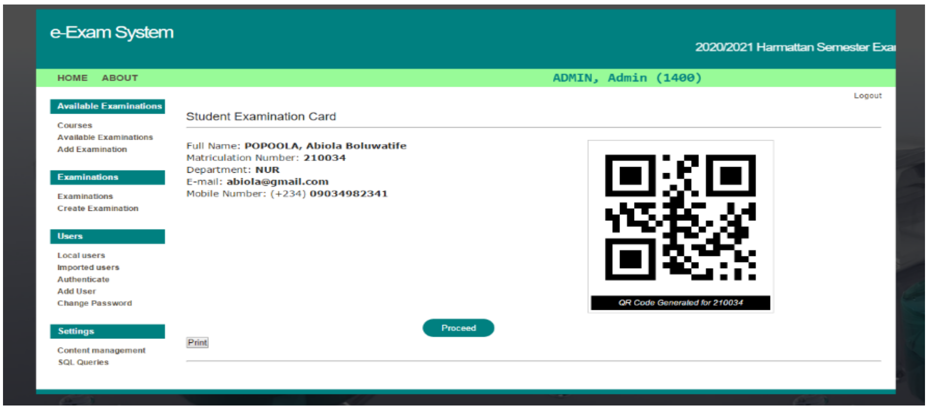
Fig. 8. User Registration Page



Add/Edit User

Name : Abiola Boluwatife
Surname : Popoola
E-mail : abiola@gmail.com
User type : User ▾
Matric No : 210034
Password : ******** ******** □ Edit
Department : NUR
Phone number : 09034982341
Approved : ☑
Disabled : □

Fig. 9. User Registration Page with Details Supplied

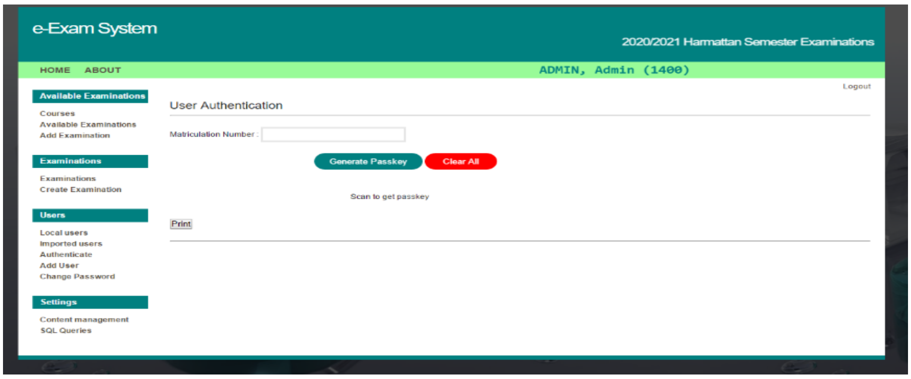


Student Examination Card

Full Name: **POPOOLA, Abiola Boluwatife**
Matriculation Number: **210034**
Department: **NUR**
E-mail: **abiola@gmail.com**
Mobile Number: (+234) **09034982341**

QR Code Generated for 210034

Fig. 10. Examination Slip Showing User Details and Generated QR Code

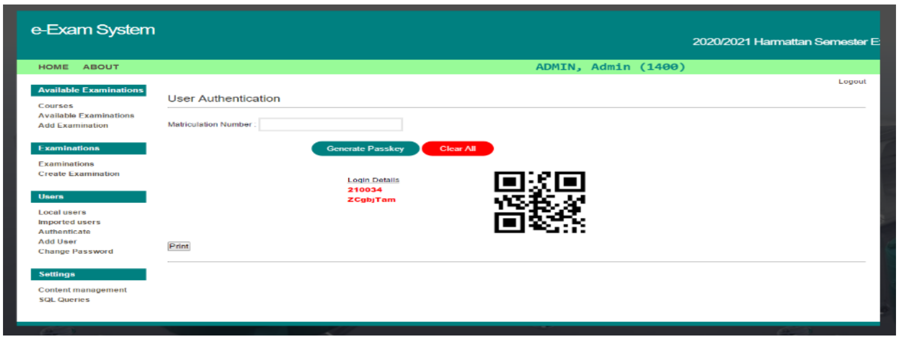


User Authentication

Matriculation Number :

Scan to get passkey

Fig. 11. Authentication Page



User Authentication

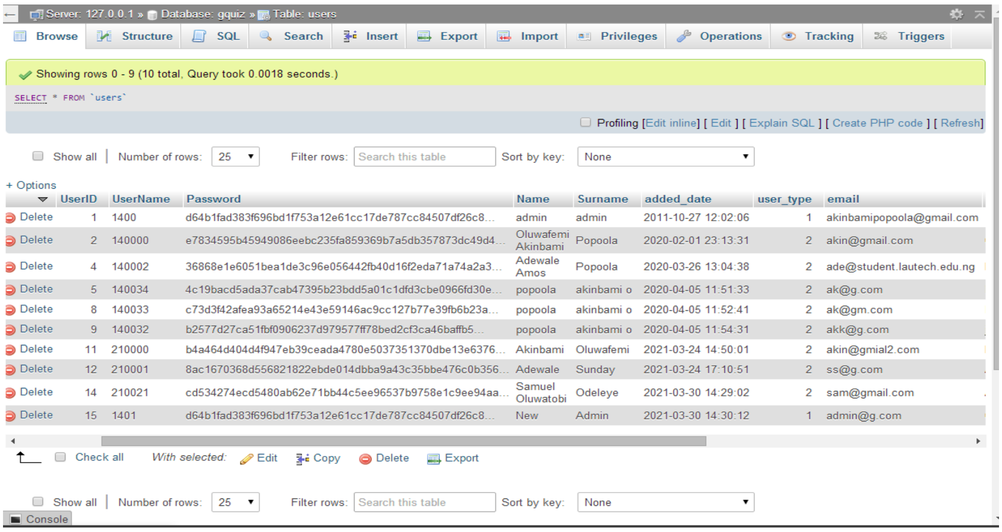
Matriculation Number :

Login Details
210034
ZCgbjTam

Fig. 12. Login Details Generated with Valid QR Code

Table 1. Encryption Algorithms' Output

Type	Value	Word Length
Plain	YEPs2LST	8
md5(Plain)	e724684d02d4c4350d92ac9fc35ea0c7	32
sha224(Plain)	c21e2e44fc6be2292aeeca545868b167f554ba193286afdd8e6b205a	56
md5(sha224(Plain))	b82a7b3427aa85ec1aeb5366aee865a9	32
sha224(md5(Plain))	d97f9d702cf325d864f06825f1aa70b5439bf88c8bc3355be5dabbc3	56



✓ Showing rows 0 - 9 (10 total, Query took 0.0018 seconds.)

```
SELECT * FROM `users`
```

	UserID	UserName	Password	Name	Surname	added_date	user_type	email
Delete	1	1400	d64b1fad383f696bd1f753a12e61cc17de787cc84507df26c8...	admin	admin	2011-10-27 12:02:06	1	akinbamipopoola@gmail.com
Delete	2	140000	e7834595b45949086eebc235fa859369b7a5db357873dc49d4...	Oluwafemi Akinbami	Popoola	2020-02-01 23:13:31	2	akin@gmail.com
Delete	4	140002	36868e1e6051bea1de3c96e056442fb40d16f2eda71a74a2a3...	Adewale Amos	Popoola	2020-03-26 13:04:38	2	ade@student.lautech.edu.ng
Delete	5	140034	4c19bacd5ada37cab47395b23bdd5a01c1dfd3cbe0966fd30e...	popoola	akinbami o	2020-04-05 11:51:33	2	ak@g.com
Delete	8	140033	c73d3f42afea93a65214e43e59146ac9cc127b77e39fb6b23a...	popoola	akinbami o	2020-04-05 11:52:41	2	ak@gm.com
Delete	9	140032	b2577d27ca51fbf0906237d979577ff78bed2cf3ca46baffb5...	popoola	akinbami o	2020-04-05 11:54:31	2	akk@g.com
Delete	11	210000	b4a464d404d4f947eb39ceada4780e5037351370dbe13e6376...	Akinbami	Oluwafemi	2021-03-24 14:50:01	2	akin@gmial2.com
Delete	12	210001	8ac1670368d556821822ebde014dbba9a43c35bbe476c0b356...	Adewale	Sunday	2021-03-24 17:10:51	2	ss@g.com
Delete	14	210021	cd534274ecd5480ab62e71bb44c5ee96537b9758e1c9ee94aa...	Samuel Oluwatobi	Odeleye	2021-03-30 14:29:02	2	sam@gmail.com
Delete	15	1401	d64b1fad383f696bd1f753a12e61cc17de787cc84507df26c8...	New	Admin	2021-03-30 14:30:12	1	admin@g.com

Fig. 13. Database Users Table Showing Encrypted Passwords

Table 2. Evaluation parameters

Parameter	Value
Error correction levels	L, M, Q and H
QR code size	10
Scanner used	PC Barcode Reader (on Xiaomi Redmi Note 9 Pro, 64MP)

Table 3. Evaluation results

Condition	Error Level	Time (seconds)
	L	3
		2
		2
		2
Without flashlight		4

Condition	Error Level	Time (seconds)
		Average = 2.6
	M	3
		4
		2
		2
		1
		Average = 2.4
	Q	0.87
		0.90
		0.87
		0.86
		0.88
		Average = 0.876
	H	0.60
		0.69
		0.60
		0.56
		0.67
		Average = 0.624
With flashlight	L	2
		2
		1
		1
		1
		Average = 1.4
	M	1
		1
		1
		1
		1
		Average = 1
	Q	0.60
		0.60
		0.60
		0.70
		0.50
		Average = 0.60
	H	0.21
		0.39
		0.48
		0.28
		0.23
		Average = 0.318

The user registration page as represented by Figure 8 is only accessible by the administrator, and is the page where the administrator supplies users details such as full names, email, matriculation number, password, department and mobile number. The matriculation number is used to generate QR codes for each user, which is then printed on the examination slip.

The authentication page is the page where the administrator authenticates and generates login details for students, by scanning the QR code on the examination slip. If the QR code is valid, student login details are generated and displayed as shown in Figure 12, else, an error message is flagged.

Table 1 shows the implementation outputs of MD5 and SHA-224 encryption algorithms using a valid password input. The 8 characters password input “YEPs2LST” produced a 32-bit length output when hashed with MD5, and the resulting 32 bits character produced a 56-bit length output when further hashed using SHA-224 which is consequently resistant to brute force attack.

4.1 System Evaluation

While trying to increase the security of an electronic examination system, the speed of processing data and generating login details should be considered. As explained, the QR code generator has four different code levels; *L* with 7% error correction, *M* with 15% error correction, *Q* with 25% error correction, and *H* with 30% error correction; also, the code size ranges from 1 to 10. The system was evaluated in terms of error correction levels and subject to two scanning conditions – with and without flashlight on. The parameters with which the evaluation was carried out are presented in the Table 2.

From the evaluation, it is revealed that the average time to authenticate a student with their quick response codes varies, depending on the QR code error level and illumination conditions. It is established that the *H error level* produces the minimum average time to scan and authenticate a user, both with and without flashlight on. With the code error level set to *H,* the average authentication time without flashlight on is 0.624secs while it is 0.318secs with flashlight on. This implies that the higher the illumination, the better the clarity, and the faster the faster the QR code reader will be.

Also, the hashed value for **“uJ72aToX”** (0b63d7de9870af74782f55ffe9bbae6442726f68ffb32a0562aa2393) was supplied as input in two online hash decoding websites (http://www.md5hashing.net/hash/sha224/ and http://www.cmd5.org/), and both threw a decoding error. This shows that it is impossible to convert or reverse the hashed values back to the initial string values, and makes the electronic system secured.

5. CONCLUSION

The secured electronic examination authentication system has been designed in such a way that students’ matriculation numbers are used to generate Quick Response codes which are used during authentication by the administrator, to generate login details for each student. Also, the system has been structured in such a way that examination questions are saved and retrieved from the database, which is only accessible by the system administrator; and each student’s options are saved in another table in the database. This makes it difficult for any unauthorized user to manipulate the examination scores, and also increases the level of trust of students in the use of the system, thereby increasing the result integrity of the system.

In addition, the security challenges have been eliminated by encrypting user details in the database (using MD5 and SHA224 algorithms). The encryption algorithms protects user details by hashing the login passwords and saving it in a format that cannot be reversed (that is, cannot be guessed). Also, with the error level set to *H,* code size set to 10 and MD5 and SHA-224 used to encrypt the login details, a fast and secure electronic examination authentication system has been developed.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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