Republic of Rwanda
Ministry of Education

RTB | RWANDA TVET BOARD

ADVANCED DATABASE DEVELOPMENT

SPEAD402

PERFORM ADVANCED DATABASE DEVELOPMENT

Competence

RQF Level: 4

Learning Hours: 50

Credits: 5

Sector: ICT and Multimedia

Trade: Software Programming and Embedded System

Module Type: Specific Module

Curriculum: ICTSPE4002 TVET Certificate IV in Software Programming and Embedded System

1200

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<table>
<tr><td>Purpose statement</td><td colspan="6">This module aims to equip learners with knowledge and skills necessary to Perform Advanced Database Development. By the end of this module, learners will be able to; Design databases, perform advanced Database manipulation, Secure Database, and Configure DBMS. The learners will be able to carry out the above tasks with minimum supervision.</td></tr>
<tr><td>Learning assumed to be in place</td><td colspan="6">- Basics of database development</td></tr>
<tr><td rowspan="6">Delivery modality</td><td colspan="2">Training delivery</td><td>100 %</td><td colspan="2">Assessment</td><td>Total 100%</td></tr>
<tr><td colspan="2">Theoretical content</td><td>20%</td><td rowspan="4">Formative assessment</td><td>20%</td><td rowspan="4">50%</td></tr>
<tr><td colspan="2">Practical work:</td><td rowspan="3">80%</td><td rowspan="3">80%</td></tr>
<tr><td>Group project and presentation</td><td>35%</td></tr>
<tr><td>Individual project /Work</td><td>45%</td></tr>
<tr><td colspan="3"></td><td colspan="2">Summative Assessment</td><td>50%</td></tr>
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Elements of Competence and Performance Criteria

Elements of competence	Performance criteria
1. Design database	1.1. Relational algebra operators are properly performed in accordance with procedural query language.
	1.2. Database Schema is properly designed according to data modelling principles
	1.3. NoSQL is properly designed In line with NoSQL Design Principles.
	1.4. Document-Oriented Databases are properly structured based on document database structure.
2. Perform advanced	2.1. PostgreSQL data manipulation commands are properly executed based database manipulation approaches.

Database manipulation	2.2. MongoDB CRUD operations are properly performed based on data manipulation structure.
	2.3. Aggregate functions, scalar functions and advanced functions are appropriately performed based on database manipulation approaches.
	2.4. Views and indexes are properly executed in line with database manipulation approaches.
	2.5. User-defined Functions and stored Procedures are properly executed in line with database manipulation approaches.
	2.6. Sequences are properly executed in line with database manipulation approaches.
	2.7. Triggers are properly executed in line with database manipulation approaches
3. Secure Database	3.1. Database authentication and authorization are properly managed based on database access control approaches
	3.2. Database Audit is appropriately performed based on database audit principles.
	3.3. SQL injection is properly managed based on database security approaches
	3.4. Database encryption is properly performed based on database security approaches.
	3.5. Database Backup is properly performed based on database security approaches
	3.6. Disaster recovery is effectively implemented based on DBMS and server requirements
4. Configure DBMS	4.1. DBMS is precisely selected based on server requirements
	4.2. Hosting server is correctly configured in line with the server installation process
	4.3. Application tools are correctly configured in line with the server installation process

	4.4. Disaster recovery is effectively implemented based on DBMS and server requirements

Intended Knowledge, Skills and Attitude

Knowledge	Skills	Attitude
✓ Identify DBMS requirements ✓ Explain database normalisation ✓ Describe relational algebra ✓ Describe data modelling principle ✓ Explain NoSQL ✓ Describe database routines(views, indexes, storage procedures, triggers) ✓ Differentiate authentication and authorisation	✓ Design the SQL and noSQL database ✓ Configure DBMS ✓ Perform advanced database Manipulation using PostgreSQL ✓ Perform NoSQL database manipulation with MongoDB ✓ Execute user defined and built in database functions. ✓ Execute stored procedures ✓ Execute Sequences ✓ Apply database views, triggers, events, cursors and indexes ✓ Secure the Database	✓ Make appropriate choice of the DBMS types ✓ Use creativity and innovation throughout the Database Management ✓ Appreciate the use of advanced features such as stored procedures, views, triggers, events, cursors and indexes ✓ Consider the security of the database

Course content

Learning outcomes	At the end of the module the learner will be able to: 1. Design Database 2. Perform Advanced Database Manipulation 3. Secure Database 4. Configure DBMS

Learning outcome 1: Design Database	Learning hours: 10

Indicative content

- **Application of Relational Algebra operators**
  - ✓ Relational Algebra
    - Types of Relational operations
    - Implementation of relational operations (basic and drivers)
  - ✓ Relational Calculus
    - Types of Relational Calculus
    - Implementation of relational calculus
- **Database Schema Design**
  - ✓ Introduction to relational database concepts
  - ✓ Normalization
    - 1NF
    - 2NF
    - 3NF
    - BNCF
  - ✓ Denormalization
- **Description NoSQL databases**

- ✓ Advantages of NoSQL
- ✓ NoSQL vs SQL
- ✓ Features of NoSQL Databases
- ✓ Types of NoSQL Databases
  - Key-Value stores
  - Document-oriented
  - Wide column
  - Graph
- ✓ NoSQL Design Principles
- ✓ Implementation of NoSQL Data Modelling Techniques
  - Conceptual Techniques
  - General Modelling Techniques
  - Hierarchy Modelling Techniques
- ✓ Structuring Document-oriented databases
  - Introduction to document-oriented databases
  - Documents
  - Collections
  - Advantages and Limitations
  - Use cases of Document-oriented databases

Resources required for the learning outcome

Equipment	Computer, server
Materials	PPT
Tools	DBMS tools (XML, **Draw.io**,**PostgreSQL**, **MongoDB**…)
Facilitation techniques	Brainstorming Group discussion Demonstration Practical exercise
Formative assessment methods /(CAT)	Oral assessment Written assessment Practical assessment Formative assessment

Learning outcome 2: Perform advanced Database manipulation	**Learning hours: 20**

Indicative content

- **Execution of PostgreSQL Data manipulation commands**
  - ✓ Introduction to PostgreSQL
    - Definition
    - Advantages of PostgreSQL
    - PostgreSQL vs MySQL
    - PostgreSQL Shell Commands vs PgAdmin 4
    - Identification of PostgreSQL Data types
  - ✓ Data definition in PostgreSQL
    - Create database
    - Create table
    - Alter table
    - Create schema
    - Modifying table
    - Drop table
    - Constraints
    - Privileges (database users, User privileges)
    - Schemas
    - Inheritance
    - Table partitioning
  - ✓ Manipulating PostgreSQL Queries and Subqueries
    - Inserting data
    - Updating data
    - Deleting data
    - Returning data
  - ✓ Execution of PostgreSQL clauses and conditions
    - Where
    - Order by
    - Group by
    - Having

- Distinct
- Limit
- Fetch

✓ PostgreSQL conditions

- IN
- LIKE
- OR
- AND

● **Implementation of Aggregate functions, scalar functions, and advanced functions**

✓ Aggregate functions in SQL database

- SUM()
- COUNT()
- AVG()
- MIN()
- MAX()
- FIRST()
- LAST()

✓ Scalar function on SQL Database

- LCASE()
- UCASE()
- LEN()
- MID()
- ROUND()
- NOW()
- FORMAT()

✓ SQL built-in date functions description and execution

- Dateadd()
- Datediff()
- DateName()
- Datepart()

- Day()
- Getdate()
- Isdate()
- Month()
- Sysdate()
- Year()

✓ SQL built-in string functions description and execution

- Concat()
- Len()
- Format()
- Replace ()
- Replicate()
- Trim()
- Upper()

✓ Execution of PostgreSQL transaction

- Properties of transaction
- Transaction control

● **Execution of View and indexes**

✓ Views in PostgreSQL Database

- Types of views
- Creation of views
- Modify a view.
- Create an indexed view.
- Delete a view.
- Materialized views

✓ Indexes in PostgreSQL Databases

- Types of indexes on SQL
- Creation of an index

● **PL/PGSQL procedural language**

✓ PL/pgSQL Overview

- Introduction

- Characteristics of PL/pgSQL
- Advantages and disadvantages of PL/pgSQL

✓ PL/pgSQL Block Structure
- Types of Block Structure
- Syntax of Block in PL/pgSQL

✓ VARIABLES & CONSTANTS
- Variables
- Data types
- Select Into
- Row Variables
- Record Types
- Constants

✓ PostgreSQL Operators
- Logical operators
- Arithmetic operators
- Compound operators

✓ Control structures
- If then
- Case when
- Loop
- While Loop
- For Loop
- Exit
- Continue

✓ User-defined functions
- Function Parameters
- Function Overloading
- Functions that Return a Table
- Privileges
- Creating UDF
- Calling UDF

- Handler writing for UDF

✓ CURSORS
- definition
- declaration of cursors
- advantages and disadvantages of cursor
- Manipulation of cursors

✓ Stored Procedures
- Create Procedure
- Procedure Parameters
- Usage of stored procedures
- Caller and owner rights
- Passing in references
- Handler writing for stored procedure.
- Stored procedure parameters
- Stored procedure return values

✓ Execution of sequences
- Features of sequences
- Sequences in PostgreSQL
- Sequence arguments/parameters
- Creation of a sequence
- Sequence Modification (Alter, Drop, Next Value For…)
- Sequence numbers

✓ Execution of Triggers
- Distinction between triggers and stored procedures
- Advantages and disadvantages
- Implementation of Triggers in PostgreSQL
- Syntax and parameters
- Types of Triggers
- Parts of a Trigger
- Trigger execution modes

- Data Access for triggers
- Retrieving triggers
- Updating triggers
- Dependency maintenance for triggers
- Delete triggers.

- **Performing MongoDB CRUD Operations**
  - ✓ Description of MongDB
    - Definition
    - Databases and Collections
    - Documents in MongoDB
  - ✓ MongoDB CRUD concepts
    - Analyse query performance.
    - Atomicity and transactions
    - Distributed queries
    - Field names with periods(.) and dollar signs ($)
    - Query optimization
  - ✓ Execution of CRUD operation
    - Insert Documents
    - Query documents
    - Update documents
    - Delete documents.
    - Bulk Write Operations
    - Retriable Writes
    - Retriable reads.
    - Text Search
    - Geospatial Queries
    - Read isolation (Read Concern)
  - ✓ Mongosh Methods in MongoDB
    - Collection Methods
    - Cursor methods

- Database Methods
- Query plan cache methods
- Bulk operation methods
- User management methods
- Role management methods
- Replication methods
- Sharding methods
- Free monitoring methods
- Object constructors and methods
- Connection methods
- Atlas search index methods

✓ Implementation of triggers in MongoDB

- Database triggers
- Authentication Triggers
- Scheduled triggers
- Disabling a trigger
- Sending Trigger Events to Cloud

Equipment	Computer
Materials	
Tools	DBMS(MongoDB Compass, PostgreSQL..)
Facilitation techniques	➢ Brainstorming ➢ Group discussion ➢ Demonstration ➢ Practical exercise
Formative assessment methods /(CAT)	➢ Oral assessment ➢ Written assessment ➢ Practical assessment ➢ Formative assessment

Learning outcome 3: Secure Database	**Learning hours: 10**

Indicative content

- **Creation of Database Authentication and Authorization**
  - ✓ Identification of user types
  - ✓ Identification of privileges
  - ✓ Managing user passwords
  - ✓ Setting password parameters
    - Lifetime
    - Lock time
    - Reusing
  - ✓ Creation of user profile resources limitation
    - Values
    - Unlimited
    - Default
  - ✓ Remote access configurations
- **Creation of Database Audit**
  - ✓ Identification of Auditing activities
    - Standard auditing
    - Fine –Grained auditing
  - ✓ Authorization to perform audit.
  - ✓ Audit trail
    - Data dictionary table
    - Operating system file
  - ✓ Enabling audit
  - ✓ Auditing statement executions
  - ✓ Audit options
    - Session
    - Access
  - ✓ Application of Standard auditing levels
    - Statement levels
    - Object levels
    - Privilege auditing
- **Encryption of database**
  - ✓ Description of Two-tier key architecture

- Presentation Layer
- Data Layer

✓ Creation of encryption keys
- Column encryption
- Table space encryption

● **Performing database backup**

✓ Introduction to database backups
- Benefits
- Potential risks of data loss

✓ Identification of backup types
✓ Description of backup strategies
✓ Backup components
✓ Implementation of backup process
- local backup
- cloud backup

✓ Recovery scenarios
✓ Testing backups

● **Implementation of disaster recovery**

✓ Description of Disaster Recovery
- Definition of a disaster in the context of database management
- Disaster Recovery Plan
- Importance disaster recovery plan

✓ Components of Disaster Recovery
- Primary database server
- Backup copies
- Standby servers
- Redundant systems

✓ Disaster Recovery vs. Backup
✓ Key Disaster Recovery Concepts
- RPO (Recovery Point Objective)
- RTO (Recovery Time Objective)

✓ Use of Standby Servers and Replication
✓ Implementation of High Availability Solutions

▪ Failover clusters ▪ Load balancing Introduction to Cloud-Based Disaster Recovery	
Equipment	Computer
Materials	
Tools	DBMS, Mongodump, mongorestore, MongoDB Atlas Backup, MongoDB Management Service, Percona Backup for MongoDB, Bacula Mongo, pg_dump, pg_restore, Redgate SQL Backup, SQLBackupAndFTP, Amazon RDS Backup, Azure SQL Database Backup
Facilitation techniques	➢ Brainstorming ➢ Group discussion ➢ Demonstration ➢ Practical exercise
Formative assessment methods /(CAT)	➢ Oral assessment ➢ Written assessment ➢ Practical assessment ➢ Formative assessment

Learning outcome 4: Configure DBMS	**Learning hours: 10**

Indicative content

- **Selection of DBMS**
  - ✓ Introduction to DBMS
    - ▪ Definition
    - ▪ Types of DBMS
    - ▪ Real time contact vendors
    - ▪ Techniques of collaboration
  - ✓ Application of DBMS selection steps
    - ▪ Define Terms of Reference of Study
    - ▪ Shortlist two or three products
    - ▪ Evaluate products.
    - ▪ Recommended selection and produce report.
- **Configuration of Hosting Server**
  - ✓ Preparation of server to receive outside request.
    - ▪ Steps of setting up server room

- Configure authoritative name server.

✓ Installation of database system
- Installation of different DBMS
- State the requirement in installation of DBMS server.

✓ Securing of the hosting server
- Set Strong password.
- Server services audit
- Remote database and access configurations

● **Installation of Application tools**

✓ Installation of application tool
- Install Application Server using installer.
- Install the Application using the command line.
- Configure the Application

✓ Activation of application tool
- Activation of application product key
- Track product key
- Monitor product key.

✓ Audition of application license
- Plan for application licence audition
- Setup an environment for application licence audition
- Perform Service Auditing

Resources required for the Learning outcome

Equipment	Computer
Materials	
Tools	DBMS(Mongodump, mongorestore, MongoDB Atlas Backup, MongoDB Management Service, Percona Backup for MongoDB, Bacula Mongo, pg_dump, pg_restore, Redgate SQL Backup, SQLBackupAndFTP, Amazon RDS Backup, Azure SQL Database Backup……)
Facilitation techniques	➢ Brainstorming ➢ Group discussion ➢ Demonstration ➢ Practical exercise
Formative assessment methods /(CAT)	➢ Oral assessment ➢ Written assessment ➢ Practical assessment

	➢ Formative assessment

Integrated/Summative assessment (For specific module)

Integrated situation

TechCommerce is a rapidly growing e-commerce company that offers a wide range of products to its customers. To optimize its operations and improve customer satisfaction, the company is embarking on a project to develop a modern order management system. TechCommerce has been facing a security issue because they were using old database technology, they needed to integrate a MongoDB database to handle the storage and retrieval of order-related data.

As a database developer, you are hired by TechCommerce to design a database schema to efficiently store and manage order-related information. This database will have a collection of all orders with information like customer identification, order date, products, total price amount and keeps the status of the order.

You will also document queries that will be used by backend developers to store new orders, retrieve new orders, change orders' information and archiving or logically deleting cancelled or completed orders.

For improving database performance, there should be indexes for customer id, order date, and status as those fields will be frequently used in querying. There should also be functions that generate reports, such as monthly sales summaries and customer purchase history. The database will also need a function to generate statistics for daily average purchases.
This database system will implement user authentication and role-based access control to ensure only authorized personnel can access and modify order data. You will need to document a backup plan for the database. Disaster recovery measures must be put in place, including replication and failover mechanisms, to ensure that the platform remains operational even in the event of server failures or data center outages.
This work should be done within 4 hours.

Assessable Outcome 1: Database Schema Design
Assessment Criteria:

- The database schema efficiently stores and manages order-related information, including customer identification, order date, products, total price amount, and order status.
- Appropriate data types are used for each attribute to ensure data integrity.
- The schema includes necessary tables, relationships, and constraints to maintain data consistency.

- The design demonstrates a clear understanding of MongoDB database technology and its integration into the project.

Assessment Outcome 2: Query Documentation
Assessment Criteria:

- Comprehensive documentation of queries for storing new orders, retrieving orders, updating order information, and archiving or logically deleting orders.
- Queries are well-optimized for performance, considering the use of indexes and proper indexing techniques.
- Documentation includes explanations of query functionality and usage for backend developers.
- Queries are organized logically and follow best practices in MongoDB query design.

Assessment Outcome 3: Report Generation Functions
Assessment Criteria:

- Functions for generating reports, such as monthly sales summaries and customer purchase history, are implemented effectively.
- Reports are accurate and provide valuable insights into order data.
- The function for generating statistics for daily average purchases is functional and produces meaningful results.

Assessment Outcome 4: User Authentication and Role-Based Access Control
Assessment Criteria:

- User authentication and role-based access control mechanisms are successfully implemented.
- Only authorized personnel can access and modify order data, and access permissions are clearly defined.
- Security measures, such as encryption and password policies, are implemented to protect user accounts and data.

Assessment Outcome 5: Backup and Disaster Recovery Plan
Assessment Criteria:

- A comprehensive backup plan for the database is documented, including backup frequency and storage location.
- Disaster recovery measures, such as replication and failover mechanisms, are described in detail.
- The plan addresses server failures and data center outages, ensuring the platform's operational continuity.
- Clear procedures for data restoration and recovery are outlined in the plan.

Assessment Outcome 6: Time Management
Assessment Criteria:

- The project is completed within the allocated time frame of 4 hours.
- Effective time management practices are demonstrated throughout the project, ensuring all tasks are completed on time.

Resources

Tools	MongoDB, MongoDB Compass, MongoDB Shell, Text Editors, ERD Tools, Database Modeling Tools, Mongodump, mongorestore, MongoDB Atlas Backup, MongoDB Management Service, Percona Backup for MongoDB, Bacula Mongo

Equipment	Computer, server
Materials/ Consumables	

Assessable outcomes	Assessment criteria (Based on performance criteria)	Indicator	Observation		Marks allocation
			Yes	No	
Design database (10%)	Design of NoSQL	Database schema is designed			3
	Structure of Document-Oriented Databases.	Orders collection is created			3
Perform advanced Database manipulation. (58%)	Implementation of MongoDB CRUD operations.	Insert query is provided			3
		Read query is provided			3
		Update query is provided			3
		Delete query is provided			3
	Implementation of Aggregate functions, scalar functions, and advanced functions	Function for average purchases is created			3
		Daily average purchases are identified			3
	Execution of Views and indexes	Index customer id is created			3
		Index for order date is created			3

		Index for order status is created			3
	Execution of User-defined Functions and stored Procedures	Function to retrieve monthly sales summary is created			2
		Function to retrieve customer purchase history is created			2
		Monthly sales summary is provided			2
		Customer purchase history is provided			2
Secure Database (18%)	Management of Database authentication and authorization	User accounts are created			3
		User roles are identified			3
	Performing Database Backup	Backup plan is provided			5
Configure DBMS (13%)	Implementation of Disaster recovery	Replication function is created			5
		Replication is performed			3
Total marks					60
Percentage Weightage					100%
Minimum Passing line % (Aggregate): 70%					

References:

1. Sabharwal, N., & Edward, S. G. (2015). *Practical MonGoDB: Architecting, developing, and administering MonGoDB*. [Open Library Link](https://openlibrary.org/books/OL27948167M/Practical_MongoDB)
2. PostgreSQL: books. (n.d.). The PostgreSQL Global Development Group. [Website Link](https://www.postgresql.org/docs/books/)
3. Mauer, L. (2022). How to Design NoSQL Databases? *RestApp*. [Website Link](https://restapp.io/blog/how-to-design-nosql-databases/)
4. Blazeclan, T. (2023). A Dive Deep into Types of NoSQL Databases. *Blazeclan*. [Website Link](https://www.blazeclan.com/asean/blog/dive-deep-types-nosql-databases/)

5. Smallcombe, M. (2019). PostgreSQL vs MySQL: The Critical Differences. *Integrate.io*. [Website Link](https://www.integrate.io/blog/postgresql-vs-mysql-which-one-is-better-for-your-use-case/)
6. MongoDB CRUD Operations — *MongoDB Manual*. (n.d.). [Website Link](https://www.mongodb.com/docs/manual/crud/)
7. Geospatial queries — *MongoDB Manual*. (n.d.). [Website Link](https://www.mongodb.com/docs/manual/geospatial-queries/)
8. Viswanathan, A., & Kumar, S. (2012, June 20). Implementing aggregation functions in MongoDB. *InfoQ*. [Website Link](https://www.infoq.com/articles/implementing-aggregation-functions-in-mongodb/)
9. A, A. (2023). SQL Functions: How to write a Function in SQL? *Edureka*. [Website Link](https://www.edureka.co/blog/sql-functions)
10. Choosing whether to write a stored procedure or a User-Defined function | *Snowflake Documentation*. (n.d.). [Website Link](https://docs.snowflake.com/en/developer-guide/stored-procedures-vs-udfs)
11. Indexing Strategies — *MongoDB Manual*. (n.d.). [Website Link](https://www.mongodb.com/docs/manual/applications/indexes/)
12. GeeksforGeeks. (2023). Difference between Simple and Complex View in SQL. *GeeksforGeeks*. [Website Link](https://www.geeksforgeeks.org/difference-between-simple-and-complex-view-in-sql/)
13. WilliamDAssafMSFT. (2023, February 28). Views - SQL server. *Microsoft Learn*. [Website Link](https://learn.microsoft.com/en-us/sql/relational-databases/views/views?view=sql-server-ver16)
14. Triggers in SQL Server - javatpoint. (n.d.). *www.javatpoint.com*. [Website Link](https://www.javatpoint.com/triggers-in-sql-server)
15. Basharat, I., Azam, F., & Muzaffar, A. W. (2012). Database Security and Encryption: A survey study. *International Journal of Computer Applications, 47*(12), 28–34. [DOI Link](https://doi.org/10.5120/7242-0218)