Republic of Rwanda
Ministry of Education

RTB | RWANDA TVET BOARD

NITID401

IoT SYSTEM DEVELOPMENT

Develop IoT system

Competence

RQF Level: 4

Learning Hours 140

Credits: 14

Sector: ICT and Multimedia

Trade: Networking and Internet Technologies

Module Type: Specific

Curriculum: ICTNIT4001 TVET Certificate IV in Networking and Internet Technologies

1200

Issue Date: September 2023

<table>
<tr><td>Purpose statement</td><td colspan="6">This specific module describes the skills, knowledge and attitude required to develop IoT system. This module is intended to prepare student pursuing TVET Level 4 in Networking and Internet Technologies. Upon completion of this module, the learner will be able to plan IoT system development, build IoT system and deploy IoT system.</td></tr>
<tr><td>Learning assumed to be in place</td><td colspan="6">▪ Basics of technical drawing</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>30%</td><td rowspan="4">Formative assessment</td><td>30%</td><td rowspan="4">50%</td></tr>
<tr><td colspan="2">Practical work:</td><td rowspan="3">70%</td><td rowspan="3">70%</td></tr>
<tr><td>Group project and presentation</td><td>40%</td></tr>
<tr><td>Individual project /Work</td><td>30%</td></tr>
<tr><td colspan="2"></td><td colspan="3">Summative Assessment</td><td>50%</td></tr>
</table>

Elements of Competence and Performance Criteria

Elements of competency	Performance criteria
1 Plan IoT system development	1.1 System requirements are properly identified based on user needs.
	1.2 Tool, materials and equipment are correctly selected according to entire system requirements.
	1.3 IoT system diagrams are correctly designed based on IoT system requirements.
2 Build IoT system	2.1 IoT circuit board is neatly designed based on IoT system requirement.
	2.2 IoT components are correctly mounted to the circuit board according to the IoT system circuit diagram.
	2.3 IoT firmware is appropriately developed according to hardware design.
	2.4 Firmware is successfully uploaded into the microcontroller based on its flashing process.
	2.5 Human Machine Interface(HMI) is properly developed based on system accessibility.
	2.6 IoT system is systematically tested based on the intended use.
3. Deploy IoT system	3.1 IoT system is adequately installed in line with operational environment
	3.2 IoT system is systematically tested according to the intended use.
	3.3 IoT system is properly documented according to IoT system functionality.

Intended Knowledge, Skills, and Attitude		
Knowledge	**Skills**	**Attitude**
✓ Describe IoT Concept ✓ Describe Sensor technologies ✓ Define embedded systems ✓ Define IDE ✓ Describe Security Concept	✓ Install IoT system. ✓ Design IOT circuit board ✓ Data Analysis Skills ✓ Applying Security Skills ✓ Integrate hardware ✓ Problem-Solving ✓ Solder Electronic component ✓ Program Microprocessor ✓ Data Processing ✓ Develop Human Machine Interface (HMI) ✓ Test IoT system ✓ Apply API Integration	✓ Innovation ✓ Collaboration ✓ Attention to Detail ✓ Adaptability ✓ Ethical Mindset ✓ Persistence ✓ Self-motivation ✓ Creativity ✓ Patience ✓ Multi-tasking

Course content

Learning outcomes	At the end of the module the learner will be able to: 1. Plan IoT system development 2. Build IoT system 3. Deploy IoT system

Learning outcome 1: Plan IoT system development	Learning hours: 30

Indicative content

- **Identification of IoT system requirements**
  - ✓ Understanding Customer requirements
    - Data collection methods
    - Validation of collected data
  - ✓ Identification of system usage
    - Functional requirements
    - Non-functional requirements
  - ✓ System feasibility
    - Technical
    - Economic
    - Legal
    - Operational
    - Schedule
  - ✓ Document system requirements
- **Selection of Tools, materials, and equipment**
  - ✓ Tools:
    - Integrated Development Environment (IDE)
    - Version control system operations (git)
    - Debugging tools

- Testing tools
- Simulation and emulation software
- Analytics and monitoring tools
- Hand tools
- Programming and flashing tools
- Microcontrollers and processors
- Sensors and Actuators
- Internet
- Connectors and Cables
- Power Supplies
- Enclosures
- Printed Circuit Boards (PCBs)

✓ Equipment:

- Computer
- Soldering Stations
- Prototyping Boards
- PCB Manufacturing Equipment
- 3D Printers and CNC Machines
- Testing and Measurement Instruments

- **Design IoT system Diagrams**

✓ High-Level Architecture Diagram

- Description
- Symbols
- Under layers of IoT architecture
- Component interaction
- Design

✓ Block diagram

- Identify the system process
- Identify the components

- Determine the connections
- Add descriptions and labels
- Review and refine

✓ Data Flow Diagram

- Identify the system scope.
- Identify the processes.
- Identify the data flows.
- Identify the data stores.
- Connect the components.
- Label the components.
- Organize the diagram.
- Validate the diagram.
- Process decomposition

✓ Flowchart Diagram

- Identify the steps and process
- Select flowchart symbols
- Arrange the symbols
- Add text and labels
- Add descriptions

✓ Use case Diagram

- Identify the actors
- Identify the use cases
- Establish relationships
- Add system boundary
- Add descriptions

Resources required for the learning outcome	
Equipment	▪ IoT Development Boards ▪ Sensors and Actuators

	▪ Communication Modules ▪ Microcontrollers and Processors ▪ Power Supplies ▪ Soldering Equipment ▪ PCB Design Software and Equipment ▪ Computer
Materials	▪ Connectors and Cables ▪ Internet ▪ Electricity ▪ Cables ▪ PCB ▪ Copper clad ▪ Soldering wire(Tin) ▪ Glue Stick
Tools	▪ IDEs ▪ Edraw Max ▪ Easyeda ▪ LucidChart ▪ Draw.io ▪ Smart draw ▪ Proteus ▪ Glue gun
Facilitation techniques or Learning activity	▪ Demonstration and Simulation individual and group work trainer Guidance group discussions
Formative assessment methods /(CAT)	▪ Written Assessment ▪ Practical Assessment ▪ Oral Assessment

Learning outcome 2: : Build IoT system	Learning hours: 85

Indicative content

- **Design IOT circuit board**
  - ✓ Schematic Design
  - ✓ PCB layout
  - ✓ Trace routing
  - ✓ Power and ground planes
  - ✓ Design Rule Check (DRC)
  - ✓ PCB prototyping and testing
- **Mount IoT components on the circuit board**
  - ✓ Application of safety measures
  - ✓ Interpret circuit board design
  - ✓ Build circuit board
    - Component placement
    - Soldering
    - Signal integrity
    - Heat dissipation
  - ✓ Housing(Enclosure)
- **Develop IoT Firmware**
  - ✓ Description of communications protocols
    - Http/Https
    - Mqtt
    - loRaWAN
    - ZigBee
    - Ethernet

- Bluetooth
- Wi_Fi
- GPRS(GSM)
- TCP/IP

✓ Preparation

- Description of firmware
- Design data structures and protocols
- Select programming language
- Set up the development environment

✓ Implementation

- Sensor integration
- Data processing
- Human machine interface

✓ Data transfer from/to external platform

- Request modes
- Response modes

✓ Security and efficiency

- Power management
- Error handling
- Optimization
- Firmware Updates (OTA)
- Prototyping and field testing
- Validation and user testing

✓ Documentation and maintenance

- Version control
- Release and maintenance

- **Upload Firmware into micro-controller**

✓ Apply the Uploading procedure

- Physical Connection Setup with the Microcontroller

- Select uploading Method (USB, UART, JTAG, ICSP)
- Compile the Firmware
- Verification and Validation of Uploaded Firmware

✓ Debugging and Security

- Debugging and Troubleshooting Tips
- Security Considerations
- Over-The-Air (OTA) Firmware Updates
- Final Testing

- **Develop Human Machine Interface (HMI)**

✓ Design

- Navigations
- Color and Contrast
- Resizable Text and Layout

✓ Sensor modalities

- Screen Reader Compatibility
- Text Alternatives
- Captioning and Transcripts
- Time Constraints
- Sound Alternatives
- Error Handling

✓ Integration of IoT circuit board with HMI

- Power connection
- Data port connection
- Enable data communication

✓ User Testing and Improvement

- **Test the IoT system**

✓ Functional Testing

- Unit Testing

- Integration Testing

✓ Performance Testing

- Reliability Testing
- Scalability Testing

✓ Security and Compatibility Testing:

- Security Testing
- Interoperability Testing
- Usability Testing
- Edge Case Testing
- Error Handling and Recovery Testing
- OTA Firmware Updates Testing

✓ Documentation

- User manuals
- Maintenance plan report

Resources required for the indicative content	
Equipment	▪ Computer ▪ Sensors ▪ Bread Board ▪ Prototyping Board ▪ Communication modules ▪ Microcontrollers ▪ Power supply ▪ Power regulator ▪ Personal Protective Equipment (PPE)
Materials	▪ Internet ▪ Wires ▪ Screw

	▪ Labelling tags
Tools	▪ Arduino IDE ▪ VS code ▪ Nextion Editor ▪ Stone Designer ▪ Simulation software ▪ Digital Multimeter ▪ Oscilloscope ▪ ESD Toolkit
Facilitation techniques or Learning activity	▪ Demonstration and simulation, individual and group work ▪ Practical exercise ▪ Individualized ▪ Trainer Guidance
Formative assessment methods /(CAT)	▪ Written assessment ▪ Practical Assessment ▪ Performance Assessment ▪ Product based assessment

Learning outcome 3: Deploy IoT system	**Learning hours: 25**
Indicative content	
• **Install IoT system** ✓ Hardware and Network Setup Interpret System Requirements document Set Up Network Infrastructure Setup IoT Devices and Sensors Setup uninterruptable power source	

- Plan for Data Storage

✓ Configuration and Setup

- Install Gateway
- Choose a Cloud Platform
- Create a Cloud Account and Set Up Services
- Test installed system

- **Test the IoT system**

✓ Functional

✓ Performance

✓ Security Testing

✓ Reliability and User Acceptance

- Reliability and Stability Testing
- User Acceptance Testing (UAT)
- Usability
- Interoperability Testing

- **Document IoT system**

✓ User manual

✓ Testing report

✓ Bill of quantities

Resources required for the indicative content	
Tools	▪ Arduino IDE ▪ IoT Web Application API ▪ Soldering Iron ▪ Calibration Tools ▪ Manuals ▪ Mounting Tool ▪ Cutting tools

	▪ Glue Gun
Equipment	▪ Microcontroller ▪ Digital Multimeter ▪ Power Supply (e.g., batteries or solar panels) ▪ Enclosure ▪ Prototyping Materials ▪ Oscilloscope ▪ Computer ▪ Screwdrivers ▪ Bread Board
Materials	▪ Internet ▪ Sensors ▪ USB Cable ▪ Soldering Tin ▪ Electricity ▪ Glue sticks ▪ Connector ▪ wires
Facilitation techniques or Learning activity	▪ Demonstration and simulation ▪ Individual and group work ▪ Trainer guided ▪ Group discussion
Formative assessment methods /(CAT)	▪ Written assessment ▪ Practical Assessment ▪ Performance Assessment ▪ Product based assessment

Integrated/Summative assessment

Integrated Situation

NN Company LTD has grown vegetables in Eastern Rwanda for several years, and it has always been concerned about water usage and crop yield as this area is sunny and hot. NN Company LTD has to secure his farming activities by implementing a smart irrigation system. NN Company LTD is willing to hire experts in IoT to develop such a smart irrigation system that will be useful to his business and neighbors. As an IoT developer, you are requested to be one of the first experts to develop this innovative technology on this farm.

Sensors that will be used to collect soil data and start an electrical pump for irrigations when the soil moisture is the inappropriate range and high temperature exceeds the Threshold values and this system will be integrated with a remote IoT web application for remote monitoring and control. Basing on the technology adopted by NN Company LTD farm collect data focusing on water usage

Information:

- Sensor calibration and maintenance will be essential to avoid false readings and incorrect irrigation schedules.
    - The system should be able to adapt quickly to weather changes and adjust irrigation schedules accordingly.
    - Integrating various components, such as sensors, and the web application, requires seamless communication and compatibility.
    - The smart irrigation system heavily relies on data transmission between sensors, embedded systems, and the web application
    - Developing energy-efficient solutions and exploring alternative power sources
    - Ensuring that the technology remains affordable for small-scale farmers like NN Company LTD will be crucial for widespread adoption.
    - Ongoing technical support will be necessary to address any issues or questions that arise.

This work is supposed to be done in 15 hours.

Resources	
Tools	▪ Arduino IDE ▪ IoT Web Application API ▪ Soldering Iron ▪ Calibration Tools ▪ Manuals ▪ Mounting Tool
Equipment	▪ Digital Multimeter ▪ 3D printer ▪ Oscilloscope ▪ Glue Gun
Materials/ Consumables	▪ IoT Development Kit (e.g., Raspberry Pi or ESP32/ESP8266) ▪ Microcontroller ▪ Power Supply (e.g., batteries or solar panels) ▪ Water pumps ▪ Water pipes ▪ Water tanks ▪ Electro valves ▪ Soil Moisture Sensors ▪ Temperature Sensors ▪ Humidity Sensors ▪ PH sensors ▪ Resistors ▪ Capacitor ▪ Relay switch module ▪ LCD display ▪ Transistor ▪ USB Cable

	▪ Soldering Tin ▪ Glue stick ▪ Isolators ▪ filament

Assessable outcomes	Assessment criteria (Based on performance criteria)	Indicator	Observation		Marks allocation
			Yes	No	
Plan IoT system development (30%)	Identification of System requirements	Customer requirements are provided			4
		system requirements are documented			5
	Selection of Tools, materials and equipment.	Tools are used			3
		Materials are used			3
		Equipment are used			3
	Draw IoT system diagrams	High-Level Architecture Diagram is drawn			3
		Block Diagram is drawn			3
		Data Flow Diagram is drawn			3
		Use case Diagram is drawn			2
Build IoT system	Design IoT circuit board	IoT circuit board Schematic is designed			2
		IoT circuit board PCB Layout			2

(40%)		is designed			
		IoT circuit board Trace Routing is traced			2
		IoT circuit board PCB Prototyping are performed			2
	Mount IoT components	IoT components are mount			2
		Mounted components are soldered			2
		IoT components are fixed			2
	Develop IoT firmware	IoT firmware development environment is prepared			2
		IoT firmware is secured			2
		IoT firmware is tested			2
		IoT firmware is documented and maintained			2
	Upload Firmware	Uploading procedure is used			3
		Firmware is debugged and secured			3
	Develop Human Machine Interface	Human Machine Interfaces are designed			2
		Sensor modalities are included			2
		Human Machine Interface is tested and improved			2

	Test IoT system is systematically	IoT system functionalities is tested			2
		IoT system performance is tested			2
		IoT system Security and Compatibility is tested			2
Deploy IoT system **(30%)**	Installation of IoT system	Hardware and Network Setup are prepared			2
		Cloud Integration are conducted			2
		deployment environment is tested			2
		IoT system Pre-Installation is prepared			3
		IoT system is configured			3
		IoT system is documented			2
	Test IoT system	IoT system functionality is tested			2
		IoT system functionality is tested			2
		IoT system performance is tested			2
		IoT system is security tested			2

		IoT system reliability and user acceptance are tested			2
	Documentation IoT system	IoT system User manual is documented			2
		IoT system Testing report is documented			2
		IoT system Bill of quantities is documented			2
Percentage Weightage					100%
Minimum Passing line % (Aggregate): 70%					

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