



TRAINING NEEDS ASSESSMENT REPORT

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ACKNOWLEDGEMENTS

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**We thank you for your continued support in
our efforts to contribute to the digital
transformation in Rwanda.**

Contact

Gesellschaft für internationale
Zusammenarbeit GIZ GmbH

Digital Transformation Center Rwanda
Career Center Building - 7th Floor
KG 541 Street
Kigali, Rwanda



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EXECUTIVE SUMMARY

The Government of Rwanda (GoR) maintains its dominant influence on the ICT sector by being a major customer of ICT talent. GoR is responsible for enacting and imposing policies and regulations affecting the overall ICT business environment. This ICT Skills-Gap Analysis was necessitated by the need to align the efforts of key stakeholders so as to bring about the successful actualization of the relevant ICT policies and strategies.

From the study findings, the interviewed ICT companies see the need for improving the skills of talent provided by the education system. Financial constraints have been compounded by the Covid-19 pandemic. The study findings establish the need for better and more adaptive, yet aggressive, approaches that will lead to attracting more girls to take up a career in ICT. The study focused on junior and senior IT professionals with the aim of assessing the existing digital skills gaps. For example, the ecosystem has professionals in emerging technologies such as IoT, Big Data and Analytics, AI, Robotics, and Blockchain.

This study has suggested a training roadmap to empower women in the ICT sector in Rwanda. The roadmap includes a discussion of potential strategic initiatives that can be undertaken to ensure a sustained approach to bridging future skills needs and promoting women's participation in ICT. It also identifies key stakeholders that will play a critical role in its implementation.

PROJECT BACKGROUND

The SMART Rwanda Master Plan outlines the major ICT priorities including the environmental factors to shape Rwanda's ICT services. The ICT Sector Strategic Plan (2018-2024) identifies seven pillars for the sector, namely; Smart Cities, Fintech, Smart Agriculture, Trade and Industry, Health, Education, Government, as well as Women and Youth Empowerment in ICT. The Digital Transformation Center supports the GoR in achieving its digitization efforts through solution development, professional development and digital literacy, startup and ecosystem support along with policy development.

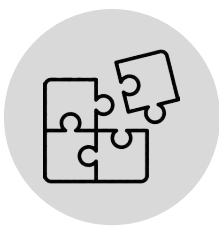
GoR has set out three key ICT enablers: ICT Capability and Capacity Development, Smart Governance in addition to secured and shared Infrastructures. In order to assess key ICT skill gaps in the private sector of Rwanda to help guide in defining needs against future ICT skill requirements, a study was commissioned by the Digital Transformation Center with its findings being presented in this report.



The aim of this study was to assess the status quo of ICT skills and identify gaps to be ready for future needs.

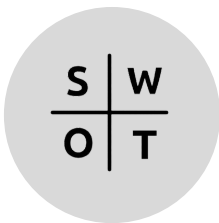
OBJECTIVE OF THE STUDY

The general objective of the study was to assess existing digital skills and assess the gaps, identify the required digital skills in the near future and draw a roadmap to build the digital skills.



01 — Identifying existing ICT Skills within Rwanda

Identify emerging technologies poised for but not limited to smart city automation (Internet of Things, Big Data and Analytics, Creative Industries and Multimedia, Mobility & Digital Lifestyle, Robotics, Block Chain, Artificial Intelligence, and e-commerce), Business readiness (business viability, valuations) among others.



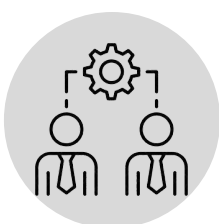
02 — Analyze the training initiatives

Define strengths and weaknesses of the approaches and provide recommendations to ensure that the approaches and training initiatives should lead to enhancement of the identified ICT skill gaps in the target population.



03 — Roadmap Training

Development of a roadmap (a training proposal) explicitly outlining how the identified ICT skills gaps can be filled through training.



04 — Training Centers

Identify potential training centers and facilitators to execute the trainings within the region, preferably within Rwanda.

STUDY FINDINGS

GENERAL FINDINGS

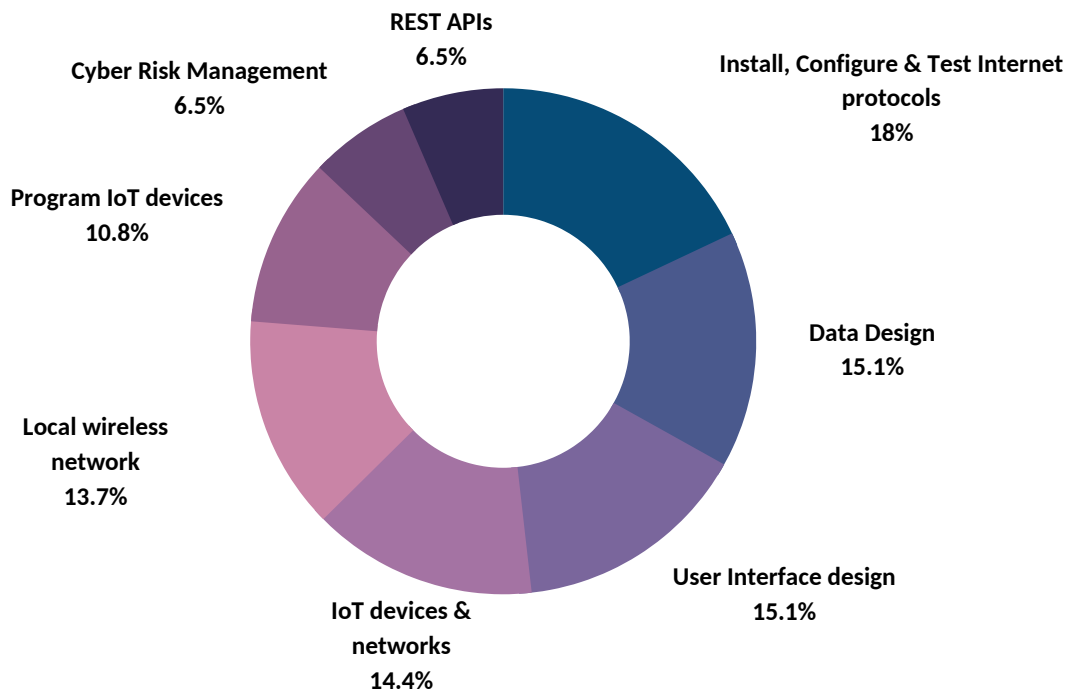
These are the key findings on existing and needed ICT skills. The table below presents an overview of the findings from focus group discussions and interviews.

Findings from ICT capacity building centers	Tech enabled companies/institutions	Key stakeholders
<ul style="list-style-type: none"> • Software engineering and web development are dominant curricula focus. • Often, fresh graduates have limited basic computing and technology skills • Female participation and involvement in the programs is low and varied in the range of 10-35%. • Students or entrepreneurs often lack communication skills which affects their ability to effectively pitch their ideas with the risk of putting potential investors off. • There is need for support on equipment and electronic components for prototyping and related activities. 	<ul style="list-style-type: none"> • Companies face difficulties hiring qualified workers from the local market. For example, fresh graduates who need some training for hands-on skills needed in workplaces. • Small companies lose their best employees to big companies even after investing into their training. • Cost of training is high, hence reluctance to invest in staff capacity building. • Although data centers exist, some companies are still having data hosted outside of Rwanda due to lack of confidence in security levels of the local data hosts. • The delay to develop national policies that guide adoption and use of emerging technologies may hinder adoption rate. • Small tech companies expressed the need for entrepreneurial skills and development of business documentation and training in financial accounting. 	<ul style="list-style-type: none"> • There is a need for appropriate policies for proper collaboration within private tech ecosystems and coordination with ICT Chambers. • ICT skills gap exist in both the private and public sectors. However, stakeholders such as RISA have focused on capacity building of the public sector. • The need for women's participation in the ICT sector is acknowledged but there are too few initiatives promoting women's participation in the sector. • Private companies play a crucial role in the adoption of emerging technologies in Rwanda. Technologies such as IoT, Big Data and Analytics, AI, Robotics, and Blockchain are already having an impact on various aspects of technology driven sustainable development. These technologies are being applied in the financial sector, Agriculture, Education, disaster management, etc.

EXISTING ICT SKILLS

The graphic and table below highlight the existing ICT skills in the private tech ecosystem based on the study findings. Besides the general knowledge and skills in ICT, the respondents highlighted some skills in emerging technology as presented in the table below.

Sample existing ICT skills among interviewees



Overview of existing ICT skills among interviewees

Skills

Description

Skills	Description
Install, configure and test internet protocols	This requires the performance outcomes, skills and knowledge required to carry out the installation of the network hardware and software.
Data design	Organize data in accordance with the database model. The designing determines what data must be stored and how the data elements interrelate.

User interface design	User interface (UI) design is the process designers use to build interfaces software or computerized devices, focusing on looks or style. The focus is to create an interface which is easy and pleasurable to the user.
Install IoT devices and networks	Applied skills in connecting, networking and communication protocols to use in web-enabled devices required IoT applications.
Build small wireless local area networks	Skills and knowledge required to build and arrange connectivity to single zone wireless local area network (WLAN).
Program IoT devices	Skills required in connecting IoT devices with wireless networks and having the ability to transmit data.
Cyber risk management	The process of identifying, analyzing, evaluating and addressing cyber security threats.
Create and develop REST APIs	Usage of a set of rules that enables different programs to communicate with one another. It outlines the appropriate way for a software developer to compose a program on a server that communicates with various client applications.
Security assessment and testing	Skills required in security assessment and tests that provide a holistic view of an organization's security tools and their effectiveness.

FUTURE NEEDED ICT SKILLS

Skill Gaps

The Rwanda private ecosystem is hungry for future skills related to emerging technologies, according to a TNA study conducted by the Rwanda Tech Association (RTA) and PricewaterhouseCoopers (PwC) in 2013-2014. Based on the findings, 85% of respondents highlighted the skill gaps as a significant obstacle that hinders them from effectively doing their job. The skill gap regarding each emerging technology is discussed below.

Internet of Things

Most of the respondents (67%) highlighted that there is a need for skill development in Internet of Things (IoT) which is presently a hot technology worldwide. Intelligent Internet of Things (IoT) enables building different IoT solutions such as innovative shopping systems, infrastructure management in both urban and rural areas, remote health monitoring and emergency notification systems, and transportation systems for e-commerce and other industries to interact with each other. The skills include how to send information back to the 'things' to actuate a given requirement, fuse raw sensor data in a meaningful way for large networks, and understand privacy and security issues.

Artificial Intelligence

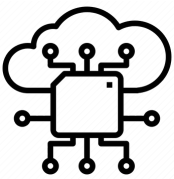
Artificial Intelligence (AI) was indicated by 60% of respondents as a technology in which they have limited capacity. Machine Learning, including Neural Networks, Deep Learning and Spiking, is considered AI. MLOps involves applying DevOps software development principles and methodologies to a Machine Learning algorithm's cycle. NLP involves the study of algorithms that take natural or human language as input. This enables the development of applications that comprehend natural languages. Three components are key in MLOps, namely: Machine Learning, DevOps and Data Engineering.

Cyber Security/Information Security

Skills and knowledge in Cyber Security were chosen by 45% of respondents. The specific Cyber Security-related skill gaps highlighted included; Network Security, Operating System Security, Database Security, Web Application Security, Digital Forensics and Cyber Crime, Ultimate Web Hacking and Cryptography.

SKILL & KNOWLEDGE GAPS

Junior IT professionals mainly need skills and knowledge related to IoT, Machine Learning, Programming (Python, Java), App-and-Web Development and Cyber Security. Below are the top 8 ICT skill gaps related to emerging technologies.



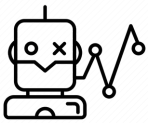
Internet of Things

- Programming of IoT devices
- Installation of IoT devices and networks
- Embedded systems programming



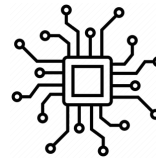
Big data and analytics

- Data analysis
- Data visualization
- Data engineering



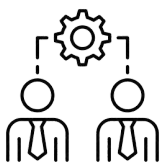
Machine Learning/AI

- Natural Language Processing, tools and applications or use scenarios
- Machine Learning operations, tools and applications or use scenarios



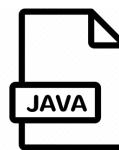
Blockchain

- Building smart contracts



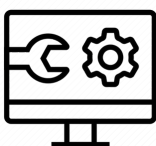
Cyber Security/Information Security

- Vulnerability assessment
- Intrusion detection
- Securing networks
- Sending data safely and securely
- Securing internet services



Programming

- Python
- Java



Software Engineering

- System design
- Agile software development methods
- Identify and address code vulnerabilities
- Secure coding practices



App and Web development

- JavaScript
- Python
- Java

NEED FOR FUTURE SKILLS

Based on the suggestions from the interviews, focus group discussions and quantitative data analysis, the following as shown in the first table below were found to be a prioritized list of technologies or fields that are much needed by junior ICT professionals. The second table shows a list of technologies or fields that are much needed by senior ICT professionals respectively.

Overview of future needed skills for junior ICT professionals

Skills	Description
Internet of Things	<ul style="list-style-type: none"> • Program IoT devices • Embedded Systems Programming • Install IoT devices and networks • Installation of IoT devices and networks • IoT based data analytics • Evaluate threats and vulnerabilities of IoT devices
Machine Learning/AI	<ul style="list-style-type: none"> • Natural Language Processing, tools and applications or use scenarios • Machine Learning Operations, tools and applications or use scenarios
Cyber Security	<ul style="list-style-type: none"> • Security program management • Threats intelligence and detection • Security assessment and testing • Security governance • Security architecture
Cloud Computing and DevOps	<ul style="list-style-type: none"> • Install and configure container orchestration services • Open source technology integration • Containerization

Big Data and Analytics	<ul style="list-style-type: none"> • Data analysis • Data visualization • Data engineering
Blockchain	<ul style="list-style-type: none"> • Developing blockchain solutions • Deploying smart contracts
Robotics	<ul style="list-style-type: none"> • Programming robots • Robots simulation with 3D graphics
Programming	<ul style="list-style-type: none"> • Java language

Overview of future needed skills for senior ICT professionals

Skills	Description
Cyber security	<ul style="list-style-type: none"> • Security Programme management • threats intelligence and detection • security assessment and testing • security governance • security architecture • evaluate threats and vulnerabilities of IoT devices
Internet of Things	<ul style="list-style-type: none"> • programming of IoT devices • Installation of IoT devices and networks • embedded systems programming • IoT based data analytics
Machine Learning/AI	<ul style="list-style-type: none"> • Natural language processing, tools and applications or use scenarios • Machine Learning Operations, tools and applications or use scenarios

Big data and analytics	<ul style="list-style-type: none">• Data analysis• data visualization• data engineering
Blockchain	<ul style="list-style-type: none">• Developing blockchain solutions• Deploying smart contracts
Cloud Computing	<ul style="list-style-type: none">• Programming• DevOps• App & Web Development (Java)
Networking	<ul style="list-style-type: none">• Programming,• DevOps,• Containerization• App & Web development (Java)• Cisco SD-WAN Solutions (300-415 ENSDWI)• CompTIA Network+• ·MCITP• Cisco CCIE Security.• MCSE

CLOSING THE SKILL GAPS

Introduce teaching materials and concepts in schools and higher education

Robotics exercises can be integrated into existing curricula whereby students could be asked to construct small machines, e.g., in agriculture lessons that take soil samples. This approach is adopted in other countries like China, where schools and universities tailor their lessons to the demand for technological skills in the future.

Encourage cross-disciplinary teaching and learning in schools and higher education

It is important that the education system focuses on imparting skills and knowledge needed in the workplace. Cross-disciplinary teaching and learning have produced good results in countries such as Finland. By focusing on problem-solving from early on, girls' minds will be wired and prepared to take up science and IT courses later on in their studies. The government can make a deliberate effort in providing drafts of teaching concepts and promoting the exchange of best practices between schools, colleges, and universities.

Create a reskilling fund to incentivize female IT professionals

Rwanda can borrow a leaf from Singapore's Ministry of Education which offers all citizens above the age of 25 an allowance of SDG 500 which they can spend on subsidized courses in future skills. The Rwanda Development Board (RDB) and relevant stakeholders can also introduce a similar initiative whereby all women in ICT, for example over the age of 22, can receive a reasonable annual amount to use on certified future skills programs.

Establish a future skills research hub for women and girls

To ensure increased women's participation in emerging technologies, a research hub exclusively for women and girls can be created that will focus on research in emerging technologies. The hub will also serve as a knowledge-sharing platform for female IT professionals, girls studying ICT and fresh IT graduates. The hub would further act as a key interface with businesses thereby ensuring that women and girls are taking up central roles in innovations in emerging technologies. To encourage companies to work with the research hub, the government can set aside a fund that could only be accessed if businesses work together with the hubs, e.g., through supporting individual research work or hackathons.

EXISTING INITIATIVES

Despite the existing skill gaps, various initiatives already exist that can aid in bridging the skill gaps. Below we highlight some of these initiatives.

WeCode

WeCode is a software development and coding training initiative by the German government for working-age Rwandan women. It is implemented with technical assistance from GIZ Rwanda in collaboration with local stakeholders, e.g., MINECOFIN, MINICT, the ICT Chamber and other relevant institutions. This program offers two courses, the introduction to programming and advanced programming.

Digital Opportunity Trust (DOT)

This is an initiative that places youth at the center of the community's economic development while providing them with critical training in digital skills. The initiative enrolls unemployed and underemployed youth who have a passion for community change into an eight-month youth leadership incubator. Since this initiative is focused on helping youth come up with social initiatives, a deliberate focus can be made to encourage technology-driven initiatives. For example, if this initiative can include youth with expertise in IoT during the program, they can debate on how IoT can be used to solve some social problems.

Rwanda Digital Schools Initiative

This is an initiative aimed at establishing Digital Schools across 8 schools in Kigali. The project aims at giving a chance to students from underprivileged communities to get exposure to ICT. This project can be scaled up to many schools across the country, especially focusing on those in rural areas where the most underprivileged are concentrated. This can offer a chance to introduce technology and its capabilities to many students whilst in secondary school, thereby increasing the chance of them taking up ICT studies later in their studies and possibly a career in IT.

Local Training Centers

Rwanda has a rich ecosystem of local training centers especially those focusing on professional training and other general training that impart fundamental skills including programming, App and Web development, and also short courses in emerging technologies. These institutions include N@com services Ltd, Andela, Rwanda, African Blockchain Institute, African Center of Excellence in IoT (ACEIoT), African Center of Excellence in Big Data, Locus Dynamics, among others.

ROADMAP IMPLEMENTATION

University of Rwanda - African Center of Excellence in Internet of Things (ACEIoT)

The Africa Center of Excellence in Internet of Things (ACEIoT) aims to educate and train African researchers in the field of IoT who will develop and deploy innovative IoT-enabled services to address development challenges across all East and South African high-priority domains in agriculture, energy, health, transportation, etc.

It offers Master's and Ph.D. programs in Internet of Things, with a specialization in Embedded Computing Systems and Wireless Sensor Networks. It also offers short training in the field of Internet of Things and related areas. The Center has two main objectives:

- To build a critical mass of African scientists and engineers in IoT through higher education and research
- To set up an IoT living lab in Rwanda for open innovation and co-creation of IoT4D

The ACEIoT has the mandate to offer training to Rwanda and regional applicants, where up to now 5 trainings have been conducted by the center as follows:

- Rapid prototyping for IoT: ACEIoT in collaboration with WAZIUP organized a 5 days training on Rapid Prototyping for Internet of Things at the University of Rwanda
- Blockchain Applications for IoT: ACEIoT in collaboration with Blockchain EXE from Japan usually organizes a five days short Course in “Blockchain Fundamentals and Applications”.
- Remote Sensing and Drones Imaging: The IEEE Geoscience and Remote Sensing Society in collaboration with ACEIoT and Rochester Institute of Technology-USA conducted a five day short course training in 2018
- LoRa Technologies: The training is jointly organized by ACEIoT and the East African Institute for Fundamental Research
- (EAI FR) of the University of Rwanda in partnership with the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste Italy.
- Drones training for civilians: The training was conducted in collaboration with the State University of Zanzibar, Tanzania.

African Blockchain Institute

The African Blockchain Institute is Africa's blockchain Think-Tank providing blockchain education and high-end deployment solutions for digital transformation in Africa. The institute partners with organizations and individuals to address their unique needs, providing options that help them reach their goals. It has a peer-reviewed curriculum that covers all major areas of knowledge relevant to blockchain technology.

Locus Dynamics

Locus Dynamics is a wholly-owned subsidiary of Ngali Holdings, focusing in Cyber Security, Aerospace, Robotics, Advanced IT systems and Solutions, and Systems integration. They have been in the Cyber Security Training industry for almost a decade, and they offer professional courses in all minor and major aspects of Information Security. Their track record includes training to Rwanda Ministry of Defense and Rwanda Information Society Authority (RISA).

E&ICT Academy, IIT Roorkee

E&ICT Academy, IIT Roorkee Electronics & ICT Academy IIT Roorkee (E&ICT IITR) is an initiative supported by MeitY, Govt of India. Courses by E& ICT IITR lay emphasis on bridging the gap between industry demand and academic approach to learning and provide a foundation to build one's career in the industries related to the ICT sector. All courses offered have projects with real-life problems to give industry insights into learning. The courses are formulated by academic and industry experts to help professionals, students, and faculty to upgrade their skills without disrupting their regular schedule.

Coursera

Coursera is a global online learning platform that offers anyone, anywhere, access to online courses and degrees from leading universities and companies. Coursera partners with more than 200 leading universities and companies to bring flexible, affordable, job-relevant online learning to individuals and organizations worldwide.

CURRICULA TO CLOSE THE SKILL GAPS

This section presents the proposed curricula that will help to impart the necessary knowledge and skills to address the skill gaps outlined. The recommended curricula outline and provide details on the course objectives, pre-requisite on knowledge and skills, course guiding topics, the target group for whom the course is designed, and training session formats/delivery modes.



BLOCKCHAIN ESSENTIALS COURSE

The proposed course outlines a blockchain essentials course, which aims to lay a solid foundation for future blockchain developers.

COURSE

BLOCKCHAIN ESSENTIALS

Training Format	Online workshop and self-paced learning
Course Duration	3 days of online workshop
Pre-requisites	No prior specific knowledge is required
Objectives	<ul style="list-style-type: none"> • Develop understanding about blockchain and its applications • Understand the designing process of blockchain solutions for business, government, corporations and multinationals • Understand how to employ blockchain in various application areas
Topics	<ul style="list-style-type: none"> • What is blockchain • The difference between blockchain & other technologies • How blockchain works • Blockchain design principles • Types of blockchains present in the market (Ardor, Ethereum, Hyperledger, Bitcoin, Curda, and EOS) • Different types of blockchain consensus algorithms such as proof of work, proof of stake and delegated proof of stake. • Public and private key basics • Practical applications and use cases of blockchain technology across sectors – agriculture, real estate, supply chain, health, social enterprise, entertainment, and governance • Cryptocurrencies such as Bitcoin and Ethereum • Technical sessions: building blockchain smart contract applications in order to explain how they are being used in real-world scenarios • Anti-money laundering (AML) and know your customer (KYC) regulations, anonymity goals, and government techniques for deanonymization of entities on blockchain • Future developments in the blockchain technology

BLOCKCHAIN DEVELOPERS COURSE

Table X shows the outline for a blockchain developer's course, it aims at imparting skills related to the development and deployment of smart contract.

COURSE

BLOCKCHAIN DEVELOPERS

Training Format	Face-to-face workshop and self-paced learning format. During the workshop, course content will be offered through presentations and discussions with a live demonstration
Course Duration	2 days of workshop followed by 3 days of self-paced learning (reading & working on assigned hands-on tasks)
Pre-requisites	<ul style="list-style-type: none"> • Knowledge of object-oriented programming • Write code in one of these: Java, C++, Python or JavaScript
Objectives	<ul style="list-style-type: none"> • Differentiate blockchain over traditional applications • Describe blockchain primitives: Bitcoin & Ethereum Architecture • Set up a smart contract development environment • Write code in Solidity & Web3 • Test and debug smart contracts • Design and implement smart contracts • Integrate blockchain into enterprise applications
Topics	<ul style="list-style-type: none"> • Blockchain technology over traditional applications • Blockchain primitives: Bitcoin and Ethereum architecture • Blockchain limitations: security, scalability, and technology • Introduction to smart contract and development environment • Writing codes in Solidity and Web 3 • Smart contract pitfalls, testing and debugging • Smart contract use cases and applications: design and implementation • Enterprise blockchain application and integrations • Considerations in building blockchain projects • Smart contract advanced topics

ARTIFICIAL INTELLIGENCE ANALYST

The proposed course aims at imparting technical knowledge and skills on how to develop Machine Learning models and interpret model results for decision making. The course is suitable for junior ICT professionals with an interest to become AI analysts.

COURSE

ARTIFICIAL INTELLIGENCE ANALYST

Training Format	Face-to-face workshop and self-managed learning format. During the workshop, course content will be offered through presentations and discussions with a live demonstration
Course Duration	5 days of face-to-face workshop and 3 days of self-paced learning (reading & working on assigned hands-on tasks)
Pre-requisites	<ul style="list-style-type: none"> • Computer science fundamentals • Basic knowledge of applied math, algorithms, and data modelling • Basic knowledge of probability and statistics • Basic knowledge of Node.js and cloud computing • Access to IBM Cloud • Exposure to the IBM Skills Academy Portal learning environment
Objectives	<ul style="list-style-type: none"> • Solve real-world problems using Machine Learning algorithms, e.g., K-means clustering, linear regression, decision tree, etc. • Use cURL commands to submit requests to and receive responses from several Watson services • Use Watson Studio to perform various tasks, e.g., create WS project, load data, manage object storage, analyze data, visualise data using PixeDust
Topics	<ul style="list-style-type: none"> • IBM Watson Services overview and setting up development environment • Machine Learning algorithms and IBM Watson • Introduction to Watson Studio • Introduction to IBM Watson Machine learning • Introduction to Natural Language Processing (NLP) • NLP concepts and components • NLP evaluation metrics • Computer Vision fundamentals • Introduction to IBM Watson Visual Recognition

ML ENGINEERING FOR PRODUCTION

The recommended curriculum focuses on Machine Learning Engineering for production specialization. It aims at teaching mastery of relevant tools and techniques to transform theoretical Machine Learning knowledge into a production-ready skillset.

COURSE MACHINE LEARNING ENGINEERING FOR PRODUCTION (MLOPS)

Training Format	Machine Learning Engineering for Production (MLOps)
Course Duration	5 days of workshop and 3 days of self-managed learning (reading & working on assigned hands-on tasks)
Pre-requisites	<ul style="list-style-type: none"> • Working knowledge of AI and deep learning • Intermediate Python skills and experience with any deep learning framework (TensorFlow, Keras, or PyTorch) • TensorFlow, Keras, PyTorch, Google's TPU, Labelbox, Gretel AI, Graphcore, Snorkel AI, Picsell.ia, MLFlow
Objectives	<ul style="list-style-type: none"> • Design an ML production system end-to-end: project scoping, data needs, modeling strategies, and deployment requirements • Establish a model baseline, address concept drift, and prototype how to develop, deploy, and continuously improve a ML application • Build data pipelines by gathering, cleaning, and validating datasets • Implement feature engineering, transformation, and selection with TensorFlow Extended • Apply techniques to manage modeling resources and serve offline/online inference requests • Use analytics to address model fairness, explainability issues, and mitigate bottlenecks
Topics	<ul style="list-style-type: none"> • Introduction to ML in production including lifecycle & deployment • Selecting and training a model • Data definition and baseline machine learning data lifecycle in production • Collecting, labeling and validating data • Feature engineering, transformation and selection • Data journey and data storage • Model management and delivery, monitoring and logging

INTRODUCTION TO IOT

This IoT introduction course aims at imparting technical knowledge and skills to enable course participants to build and deploy IoT systems.

COURSE

INTRODUCTION TO INTERNET OF THINGS

Training Format	Workshop format and self-managed learning. Content will be offered through presentations and live demonstrations.
Course Duration	5 days of workshop and 3 days of self-managed learning (reading & working on assigned hands-on tasks)
Pre-requisites	<ul style="list-style-type: none"> • Computer science fundamentals • Programming knowledge in C/C++/Python
Objectives	<ul style="list-style-type: none"> • Develop a clear understanding of what IoT is • Define basic terminology e.g., sensing, actuating • Understand the basics of IoT networking principles, interoperability, and cyber security • Create simple Arduino programs • Integrate sensors and actuators with Arduino and Raspberry Pi • Develop a prototype for an industrial case study: agriculture, smart homes, healthcare, activity monitoring, etc.
Topics	Recommended software and hardware tools
IoT & enabling technologies	<ul style="list-style-type: none"> • Wireless & sensor networking, Bluetooth, Bluetooth Low Energy, ZigBee, Z-Wave, 6LoWPAN, LoRa WAN
Open source	<ul style="list-style-type: none"> • Arduino, Raspberry Pi 4, Beaglebone, Intel Galileo, NodeMCU, Jetson Nano
Architecture & tech stack	<ul style="list-style-type: none"> • ISO, OSI, TCP/IP, CoAP, MQTT
IoT simulation tools	<ul style="list-style-type: none"> • Fritzig, Zetta, Arduino, OpenRemote, Node-Red, Flutter, M2M Labs
Data management tools	<ul style="list-style-type: none"> • MongoDB, NoSQL, Firebase

EDGE IMPULSE FOR IOT

This recommended course imparts technical knowledge and skills on using existing tools and techniques for deploying IoT systems at the network Edge.

COURSE EDGE IMPULSE FOR IOT WITH AI/ML/DL

Training Format	Face-to-face workshop and seminars
Course Duration	2 days of workshop and 2 online seminars
Pre-requisites	<ul style="list-style-type: none"> • Working knowledge of AI and Deep Learning • Intermediate Python/C/C++ skills • Experience working with any Deep Learning framework (TensorFlow, Keras or PyTorch)
Software & hardware requirements	<ul style="list-style-type: none"> • Edge Impulse • Anaconda • Google Colab • Jetson Nano • Raspberry Pi 4
Objectives	<ul style="list-style-type: none"> • Develop a clear understanding of Edge IoT and appreciate its relevance with AI/ML/DL • Understand application-based designing using Edge IoT • Master the skills to model and port with any Edge device, e.g., Jetson Nano/Jetson TX2/Jetson Xavier NX or equivalent • Develop and implement ideas relevant to Edge porting
Topics	<ul style="list-style-type: none"> • Introduction to IoT Edge and Edge Impulse • Introduction to data, information and knowledge • Data collection techniques • Data cleaning and pre-processing techniques • Data augmentation techniques • Modeling • Training and testing the model • Model transfer to target device and test • Introduction to transfer learning • Train, test and model port to target

SOFTWARE ENGINEERING FUNDAMENTALS

The recommended curriculum aims to impart technical knowledge and skills that will allow the course participants to apply best practices in software engineering.

COURSE SOFTWARE ENGINEERING FUNDAMENTALS

Training Format	Online workshop with virtual presentations, discussions and demonstrations
Course Duration	5 days
Pre-requisites	<ul style="list-style-type: none"> • Computer Science fundamentals • Knowledge of at least one or more programming languages: C, C++, Java, Python
Software & hardware requirements	<ul style="list-style-type: none"> • Amazon Web Services • MS Project: project and program management software • Jenkins: open source automation server written in Java • Apache ANT • Visual Studio • Kubernetes
Objectives	<ul style="list-style-type: none"> • Apply Agile software development method, Git Workflows • Know how to introduce security during requirement engineering and system design phase • Know common vulnerabilities related to coding • Identify coding problems related to security • Apply secure coding practices to fix insecure programs
Topics	<ul style="list-style-type: none"> • Agile methods • Git workflows • Secure coding (in C/C++, Java) <ul style="list-style-type: none"> - Secure software engineering process - Common code vulnerabilities - Defensive coding • Software testing <ul style="list-style-type: none"> - Code review and static analysis - Testing basics - Security testing

CLOUD COMPUTING & DEVOPS

This course aims to impart technical knowledge and skills to use various tools and technologies of DevOps and the cloud. The course is suitable for cloud infrastructure engineers and ICT professionals looking to become cloud computing and DevOps experts.

COURSE

CLOUD COMPUTING & DEVOPS

Training Format	Online workshop with virtual presentations, discussions and demonstrations
Course Duration	5 days
Pre-requisites	<ul style="list-style-type: none"> • Computer Science fundamentals • Knowledge of at least one or more programming languages: C, C++, Java, Perl, Python
Software & hardware requirements	<ul style="list-style-type: none"> • Amazon Web Services • MS Project: project and program management software • Jenkins: open source automation server written in Java • Apache ANT • Visual Studio • Kubernetes
Objectives	<ul style="list-style-type: none"> • Understand skills needed to be successful in a cloud engineering role • Understand Cloud Deployment Models, characteristics benefits, challenges • Create custom containers in docker • Deploy multi-tier websites on AWS • Internalize infrastructure and platform services provided by cloud platforms • Interact with various cloud platforms
Topics	<ul style="list-style-type: none"> • Introduction to cloud computing, and distributed and parallel computing • AWS solutions architect associate certification • Interoperability and service monitoring • Resource management and load balancing • Migration and fault tolerance • DevOps tools • Cloud security • Virtualization • Overview of cloud platforms, big data systems, and cloud-based technologies

INTRODUCTION TO DATA SCIENCE

The table below shows the recommended curriculum for a course on introduction to data science. The course introduces learners to the field of data science and data analytics. The course is suitable for junior ICT professionals with an interest to become data scientist professionals.

COURSE INTRODUCTION TO DATA SCIENCE

Training Format	Online workshop with virtual presentations, discussions and demonstrations
Course Duration	5 days
Pre-requisites	<ul style="list-style-type: none"> • Knowledge of programming in Python/R • Basic knowledge of MySQL
Software & hardware requirements	<ul style="list-style-type: none"> • Access to computers with internet access • Access to Python, SQL, and Matplotlib
Objectives	<ul style="list-style-type: none"> • Provides knowledge on all key techniques such as ETL, and R programming • Visualization with R packages • Automated knowledge acquisition • Storytelling and dashboard design
Topics	<ul style="list-style-type: none"> • Introduction to data science and its processes • Data science project lifecycle (OSEMN framework) • Linear regression analysis and statistical data modeling techniques • Introduction to Python with SQL • Visualization with Matplotlib including backend, artist and scripting layer, visualization tools, and plotting libraries • Introduction to database systems including E-R model construct, E-R notations, entities, attributes, relationships, and cardinality • Design and develop database systems using SQL with a focus on integrity constraints, transforming E-R diagrams into relations, normalization, dependency diagrams, SQL definition, and manipulation commands

BIG DATA ANALYTICS

This course introduces learners to Data Analytics tools and imparts technical knowledge and skills to use various Big Data Analytics tools and techniques. The course is suitable for junior and senior ICT professionals with experience working as data scientists.

COURSE

BIG DATA ANALYTICS

Training Format	Face-to-face workshops
Course Duration	5 days
Pre-requisites	<ul style="list-style-type: none"> • Knowledge of programming in Python/R/Julia • Basic knowledge of MySQL
Software & hardware requirements	<ul style="list-style-type: none"> • Access to computers with internet access • Access to Python, SQL, and Matplotlib
Objectives	<ul style="list-style-type: none"> • Provides knowledge on all key techniques such as ETL, and R programming • Visualization with R packages • Automated knowledge acquisition • Storytelling and dashboard design
Topics	<ul style="list-style-type: none"> • Introduction to data science and its processes • Data science project lifecycle (OSEMN framework) • Linear regression analysis and statistical data modeling techniques • Introduction to Python with SQL • Visualization with Matplotlib including backend, artist and scripting layer, visualization tools, and plotting libraries • Introduction to database systems including E-R model construct, E-R notations, entities, attributes, relationships, and cardinality • Design and develop database systems using SQL with a focus on integrity constraints, transforming E-R diagrams into relations, normalization, dependency diagrams, SQL definition, and manipulation commands

CYBER-SECURITY FUNDAMENTALS

This course aims to equip learners with technical knowledge and skills to assess security risks inherent in computer networks and the technologies that can be employed to counter such risks. The course is suitable for junior and senior ICT professionals with sufficient networking knowledge.

COURSE

CYBER-SECURITY FUNDAMENTALS

Training Format	Face-to-face workshop and seminars focusing on most vulnerable sectors
Course Duration	5 days of workshop and 2 days of self-managed learning (reading assigned materials and working on assigned hands-on tasks)
Pre-requisites	<ul style="list-style-type: none"> • Good knowledge of computer networking (CCNA, CCNP) • Intermediate C/C++/Python programming skills
Software & hardware requirements	<ul style="list-style-type: none"> • Networked computers with peripheral devices, such as printers and scanners, plus Internet access, routers, and firewalls • Wireless devices • Software: Network/server software, security software, Adobe Photoshop, VPN server and client software, Remote desktop application e.g., www.logmein.com or any suitable open source software
Objectives	<ul style="list-style-type: none"> • Understand the functioning principle of popular cryptographic primitives • Assess security and privacy vulnerabilities using widespread tools • Understand firewall architectures and their limitations • Create a virtual private network • Master techniques for achieving remote computer or network access • Understand and implement the various security protocols for securing wireless networks
Topics	<ul style="list-style-type: none"> • Cryptographic fundamentals • Public Key infrastructure • Web security and email security • Data protection • Vulnerable assessment terms & tools • Authentication, access control, firewalls, VPN, remote access technologies, and wireless security

SECURITY ASSESSMENT & TESTING

The table below proposed a curriculum for security assessment and testing. The course is suitable for junior and senior ICT professionals, especially in the financial service sector.

COURSE SECURITY ASSESSMENT & TESTING

Training Format	Face-to-face workshop
Course Duration	4 days
Pre-requisites	<ul style="list-style-type: none"> • Knowledge of Cyber-Security
Software & hardware requirements	<ul style="list-style-type: none"> • Networked computers with peripheral devices, such as printers and scanners, plus Internet access, routers, and firewalls • Wireless devices • Software: Network/server software, security software, Adobe Photoshop, VPN server and client software, Remote desktop application e.g., www.logmein.com or any suitable open source software
Objectives	<ul style="list-style-type: none"> • Understand the role of security assessments • Differentiate security assessment from security testing • Master the use of approaches, tools, and techniques of security assessment and testing • Impart hands-on experience on penetration testing, performance reconnaissance, network assessment and testing, and vulnerability assessment • Web application security assessment and testing
Topics	<ul style="list-style-type: none"> • Security assessment process • 3-phase approach in security assessment including reviewing, examination, and testing phase • Areas of focus in security testing including authentication, authorization, availability, confidentiality, and integrity\non-repudiation • Approaches, tools, techniques and types of security testing (e.g. vulnerability and security scanning, penetration testing, ethical hacking) • Classes of threats and vulnerabilities in the security assessment and testing • Penetration testing using opensource tools (e.g., Wireshark, Nmap)

ROBOTIC SYSTEMS

This course serves as an introduction to the design and implementation of robotic systems. It aims to impart technical knowledge and skills to enable participants to design and implement robotic systems. The course is suitable for junior and senior ICT professionals interested in robotics.

COURSE

ROBOTIC SYSTEMS

Training Format	Face-to-face workshop
Course Duration	4 days
Pre-requisites	<ul style="list-style-type: none"> • Knowledge of Programming in Python, C/C++ • Knowledge of working with sensors and controllers' electronics
Software & hardware requirements	<ul style="list-style-type: none"> • Whisker switches • Arduino controllers, Shield-Bot for Arduino, Board of Education Shield for Arduino • Phototransistors, IR detector
Objectives	<ul style="list-style-type: none"> • Understand the structure and applications of industrial robots • Understand robot kinematics, coordinate frames, and Jacobian matrices • Use Python to compute the position and orientation of robot's end-effector from robot joint variables and vice versa • Program robot motion in Python • Simulate robots with 3D graphics
Topics	<ul style="list-style-type: none"> • Technology testbed such as Arduino platform and sketches, Shield-Bot and board of education shield • Shield-bot and open-loop navigation with a focus on Assembly diagrams, subsystems, open-loop movements, modifying programs and mechanisms • Robotic navigation including the sensor module: Pixycam, sensing vs. perception, 2D coordinate system, Pseudocoding: planning and writing programs as well as self-parking • Sensors and signals with a focus on digital vs. analog inputs, whisker switches, phototransistor, IR detector, and multi-sensor navigation

AI FOR ROBOTICS

The recommended course below is suitable for senior ICT professionals (also junior engineers) with an interest to program and create robots through AI basic methods.

COURSE

AI FOR ROBOTICS

Training Format	Face-to-face workshop
Course Duration	5 days
Pre-requisites	<ul style="list-style-type: none"> • Knowledge of Programming in Python, C/C++ • Knowledge of working with sensors and controllers' electronics • Basic understanding of computer science and engineering • Familiarity with probability concepts and linear algebra
Software & hardware requirements	<ul style="list-style-type: none"> • Python editors & IDE's (Pycharm, Jupyter, Spyder, etc) • Machine Learning modules (scikit-learn library, xcopy, nltk) • AI programming tools e.g., classical AI – LISP, prolog, Tensorflow • WebGL, JavaScript, HTML5, JQuery • ROS with Python, Gazebo, Rviz, AirSim, MatLab
Objectives	<ul style="list-style-type: none"> • Implement filters (Kalman and particle) to enable robots to locate moving objects in the environment • Implement search algorithms and motion planning • Implement PID controls to regulate a robot's movement • Implement SLAM algorithms to enable a robot to map out an environment
Topics	<ul style="list-style-type: none"> • Overview of AI and robotics • Localization of robots using sensors to assess location and environment • Robotic motion (exact / inexact, sense / move) • Probability tools such as Baye's rule, theorem of total probability • Estimating vehicle state using Kalman filter • Tracking robots using the Particle Filter • Planning and search methods • Programming AI robots and PID control • Mapping and tracking using SLAM • Troubleshooting robots

CLOSING REMARKS

The Training Needs Assessment has shown the strengths and weaknesses of the current capacities in regards to knowledge of ICT skills. In total, 14 curricula were proposed to close skill gaps identified in Rwanda to be ready for future ICT trends. The knowledge, skills, and abilities that will be acquired through the implementation of this plan will accelerate the adoption of emerging technologies which have proven to be key in driving sustainable development.

During the study mission, women were asked about key factors affecting women's participation in ICT and whether they would prefer women-tailored training. Most women did not mention the training environment as a factor contributing to the low participation in ICT by women. However, the fact that women's participation in ICT remains low implies there is a need for women-tailored training initiatives to increase the number of female ICT professionals in the sector. This training roadmap has made efforts to outline initiatives that can be undertaken to promote women's participation in the sector.