IoT Fundamentals 2.01

Curriculum Scope and Sequence

Last updated August 2017

Introduction

The IoT (Internet of Things) Fundamentals curriculum provides foundational skills for the different aspects of the IoT. The interconnection of previously unconnected devices to the Internet and the analysis of the data generated by them, are having disruptive and transformational effects on every industry around the world. IoT is the technology that is narrowing the distance between the physical world and the digital world[1], and creating unprecedented automation in every industry. In parallel, this newly digitized world generates an increasing amount of data that can be extracted to gain insights or automate smart behaviors. The exponentially increasing availability of data is increasing the demand for professionals with the skills to reap the benefits of this growing ocean of data. That is why data-related jobs are considered to be "the sexiest jobs of the 21st century"[2]. Together, IoT and Big Data and Analytics are the prominent driver of what is becoming known as the Fourth Industrial Revolution. Perhaps even more importantly, these technologies can be applied to tackle global social problems in many areas such as optimizing our global energy usage, monitoring the environment for natural disasters, improving our health and well-being, and personalizing education.

This impact across industries globally requires professionals with a new interdisciplinary skillset: a combination of technical skills, business understanding, and creative problem-solving. At the same time, business automation will eliminate the need for many jobs—especially low-skilled jobs. As most recently communicated at the World Economic Forum[3], the greatest global risk is unemployment or underemployment in the new digital economy. As a Corporate Social Responsibility education program, helping to close this new and fast-growing skills gap by preparing students for the secure technology-related jobs of the future is a key focus of the Cisco Networking Academy. Our program constantly conducts extensive research with employers on the skills needed to build a strong foundation for many different IoT- and data analytics-related careers and, just as important, we research how to successfully teach these skills. IoT Fundamentals is our first step toward preparing students with the right skillset and mindset to successful work in the new digitized business and society.

Using an interdisciplinary approach that includes networking, electronics, programming, data analytics, security, design, and business, the IoT Fundamentals curriculum equips students with a Global Problem Solver mindset and skillset, and fuels their imagination through a deeper understanding of the transformative impact Internet of Things, Big Data, and data analytics technologies are having on business and in solving social issues. Our student-centric approach is steeped in hands-on and problem solving experiences that translate into the student being able to ideate, design, prototype, and present an IoT solution for an identified business or society need.

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[1] Manyika et al "The Internet of Things: mapping the Value beyond the hype. McKinsey Global Institute, McKinsey Company, New York June 2015"

[2] https://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century

[3] http://www.businessinsider.com/wef-global-risks-report-2017-not-brexit-populism-but-unemployment-energy-prices-2017-1?r=UK&IR=T

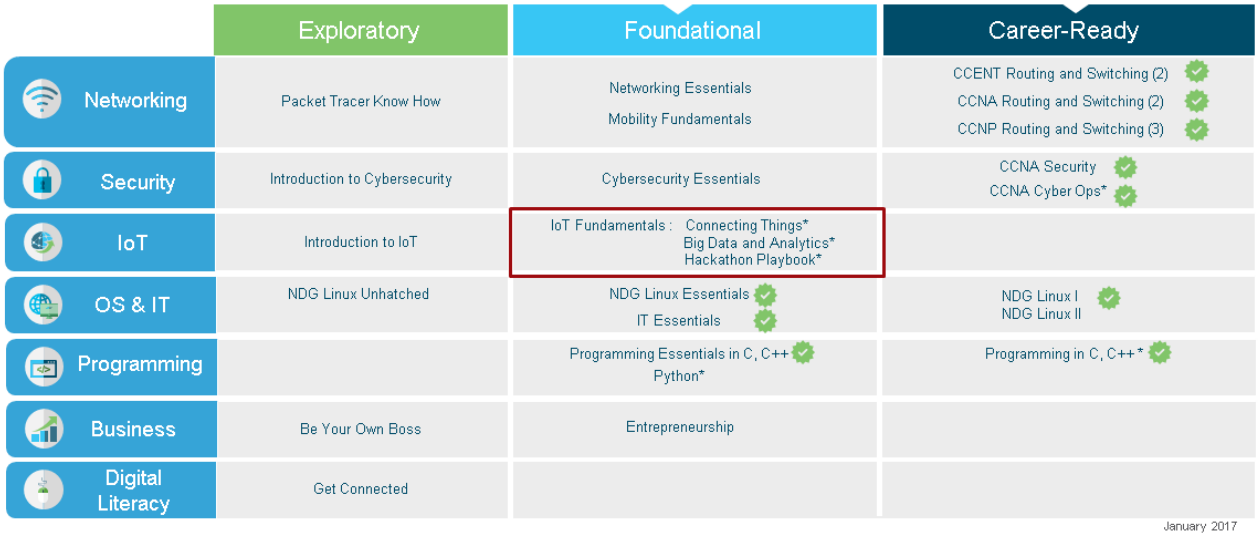
Target Audience

The IoT Fundamentals curriculum is designed for Cisco Networking Academy® students who are seeking to acquire the foundational skills and knowledge required across the emerging digitization technologies using a hands-on, problem-solving approach. The IoT Fundamentals curriculum has been designed to be modular and flexible in order to adapt appropriately for students at many education levels and types of institutions, including secondary schools, career and technical schools, universities, colleges, and community retraining centers. Since this is a new domain not previously taught at most education institutions, this curriculum also includes robust instructor training offerings that help ensure successful, high-quality outcomes for the students.

Curriculum Overview

IoT Fundamentals belongs to the Foundational category in the Networking Academy portfolio. Foundational offerings develop a solid conceptual understanding and hands-on practice with beginning and intermediate skills that are the basis for multiple Career-Ready learning paths. In the fast-changing world of IoT, it is critical for our Networking Academy students to focus on the technical and soft skills that are common across many career specializations.

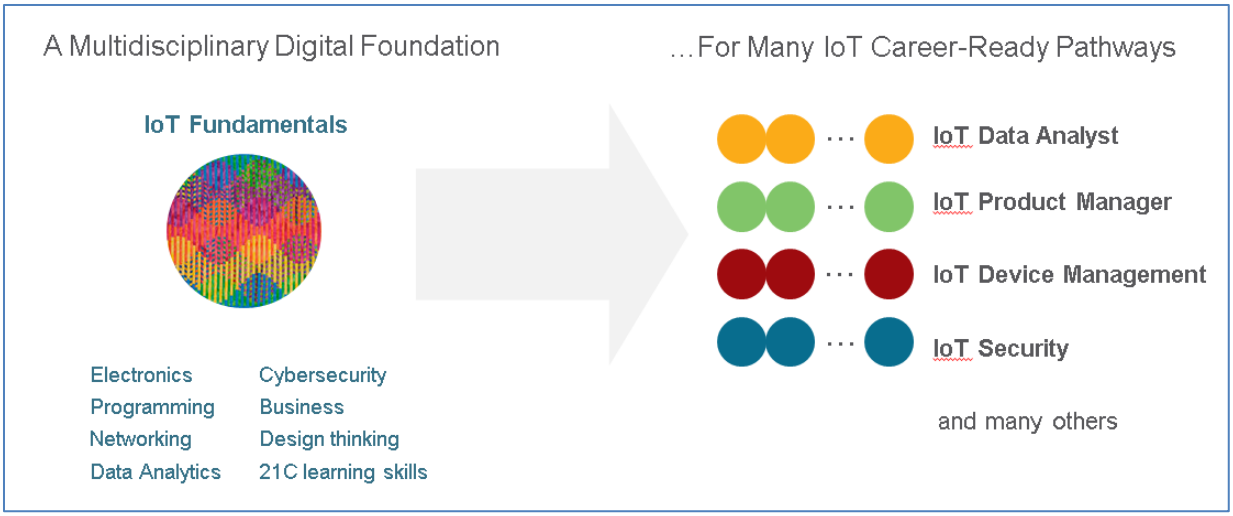
Figure 1. IoT Fundamentals is a Foundational curriculum within the NetAcad Learning Portfolio



Cisco is working closely with industry researchers such as Gartner to identify the IoT job families and the skills associated with them. In addition, Cisco is actively validating the skills and instructional approaches for teaching these skills with both employers and students in pilot projects.[4] Figure 2 positions IoT Fundamentals as providing the multidisciplinary foundational skills needed for the many different IoT Career-Ready learning paths emerging in the job marketplace today.

[4] Skillzone pilots http://csr.cisco.com/skillzone.

Figure 2. IoT Fundamentals' multidisciplinary skills foundation aligns to many IoT and Big Data specializations



The IoT Fundamentals curriculum addresses the main stages involved in digitization:

- Identifying and communicating a business or social problem
- Designing and connecting IoT devices to capture data and control the physical world
- Collecting and managing datasets
- Data visualization
- Presenting outcomes to experts that may choose to take their idea to market

It covers the core and emerging topics needed to achieve these outcomes, such as prototyping, programming IoT devices, electronic circuit design, network connectivity, IoT security, data visualization, and much more.

The consistent instructional approach across the IoT Fundamentals curriculum is developing the creative "Maker" mindset. Makers are enthusiasts who learn about technology by playing with it. The maker instructional approach is accomplished by tinkering, prototyping, iterating in a lab environment modeled after "Maker Spaces", and then transitioning the students to understand how those concepts can be applied at the enterprise level to transform business.

The curriculum has been precisely engineered with many features to help students explore and understand the domain, outlined below:

- Rich multimedia content, including interactive activities, videos, games, and quizzes addresses a variety of learning styles to help stimulate learning and increase knowledge retention.
- Cisco Prototyping Lab to facilitate hands-on labs using a blend of Maker-grade technologies such as Raspberry PI and Arduino, and Enterprise-grade technologies such as Webex Teams.
- Packet Tracer simulation-based learning activities help students develop critical thinking and complex problem solving skills by designing realistic models of real or imagined implementations.
- Assessments provide immediate feedback to support the evaluation of knowledge and acquired skills.

- Hackathons are used as a learning tool to reinforce and apply the skills students have acquired to date in the context of identifying a business or social need, building and working on a team to design a prototype of a solution that solves, in whole or in part, the identified need, and presenting their solution to their peers and an "expert" panel.
- Technical concepts are explained using language that works well for learners at all levels and embedded interactive activities break up reading of the content and help reinforce understanding.

This highly engaging curriculum encourages and excites students to consider continuing their education by specializing in high-demand technology-related career learning pathways.

Courses and recommended Curriculum Paths

The IoT Fundamentals curriculum consists of 3 courses: Connecting Things, Big Data & Analytics and the Hackathon Playbook.

Table 1: Course attributes

Course Name	Connecting Things	Big Data & Analytics	Hackathon Playbook
Primary Target Audience	Secondary, Vocational, College, University	College, University	Secondary, Vocational, College, University
Instructor Training	Yes	Yes	Yes
Instructional Hours	40-50 hours	40-50 hours	Recommend 20-30 hours distributed over 3 days, but flexible
Instruction Model	Instructor-led	Instructor-led	Instructor-led
Languages	English	English	English

There are two key concepts in creating any Internet of Things solution: Connect the Unconnected and then transform Connections into Insights.

The courses can be used in many different learning scenarios. The two recommended combinations are:

- **Connect the Unconnected** path starts with the course Connecting Things and culminates with the Hackathon Playbook course.
- **Connections into Insights** path starts with Connecting Things, progress with Big Data & Analytics and then culminate with the Hackathon Playbook.

Figure 3. NetAcad IoT Fundamentals Connect the Unconnected Path

The “Connect the Unconnected” path, which is the recommended starter path for IoT Fundamentals, prepares the students with the technical and soft skills needed to ideate, design, prototype, and present the business value of an end-to-end IoT solution. The typical end-to-end solution will include sensors and actuators, gateways, wired and wireless network connections and cloud services. This path is recommended for secondary STEM and vocational programs, 2-year college career programs, vocational training centers and Maker spaces (e.g. Fab lab, Hacker space).

Students who successfully complete both courses of the “Connect the Unconnected” path will be able to:

- Understand and explain the concepts, opportunities, and challenges of digital transformation using IoT.
- Design and model IoT solutions using simulation tools such as Cisco Packet Tracer 7.1.
- Design and prototype IoT solutions using electronics, microcontrollers like Arduino and single board computers such as Raspberry Pi.
- Securely connect the prototype to the Internet.
- Use Python to program the behavior of the IoT devices and to connect them to cloud services via APIs such as Webex Teams.
- Work as a team and apply the User-Centered Design Approach (“design thinking”) to develop, rapidly prototype, iteratively refine, and pitch a business idea for an IoT solution (Hackathon).

Note that, concerning the data aspect of an IoT solution, this path provides a basic comprehension of data analytics; however, at this level the students are not expected to apply this knowledge within a Hackathon.

Figure 4. NetAcad IoT Fundamentals “Connections into Insights”

“Connections into Insights” is the extended path. It covers 360 degree aspects of IoT, expanding the skillset of the students especially on the data analytics and Big Data systems of the IoT Solution prototype. It includes extensive hands-on labs relative to data acquisition from sensors and video cameras, data visualization and an introduction to machine learning. It enhances the communication skills and business acumen teaching storytelling with data. Introduce the students to the field of Big Data engineering platforms. The capacity to leverage the data analytics in IoT Solutions is strategically important for value creation and requires the development of specific data analysis skills that are extremely valuable in the market.

Since the Big Data & Analytics course requires more programming experience, the extended path is recommended for adoption in 2 year-college, 4 year-college, and University degree programs.

Students who successfully complete the “Connections into Insights” path will be able to:

- Understand and explain the concepts, opportunities and challenges of digital transformation using IoT.

- Design and model IoT solutions using simulation tools such as Packet Tracer.
- Design and prototype IoT solutions using electronics, microcontrollers like Arduino and single board computers such as Raspberry Pi.
- Use Python to collect, transform, analyze, and visualize data from a sensor and store it in SQL data bases.
- Conduct exploratory data analysis activities.
- Apply a basic machine learning model to data.
- Present and communicate data using storytelling.
- Describe the evolution of data management technologies from SQL to NoSQL.
- Explain the fundamental principles of a modern data center and of a distributed scalable Big Data platform like Apache Hadoop.
- Securely connect the prototype to the Internet.
- Use Python to program the behavior of IoT devices and to connect them to cloud services via APIs.
- Work as a team and apply the User Centered Design Approach ("design thinking") to develop, rapidly prototype, iteratively refine and pitch a business idea for an IoT solution (Hackathon).

Table 2: Target audience for recommended learning paths

Path Name > Feature v	Connect the Unconnected	Connections into Insights	Connections into Insights (compressed)
Description	Starter Path	Extended Path	Compressed Path
Target	Secondary Schools, Vocational Training Centers and 2-year colleges Maker spaces	2-year college, 4-year college and University	4-year Engineering program
Instructional Hours	70 hours	140 hours	70 hours
Fit in semester structures	1 semester	1st semester: Connecting Things and Hackathon (70) 2nd Semester: Big Data & Analytics and Hackathon(70)	Compress the extended path in one semester: Connecting Things (20) Big Data Analytics (30) Hackathon Playbook(20)
Prototype sophistication	IoT prototype connecting sensor to gateway and to Cloud service	IoT prototype connecting sensor to gateway and to Cloud service and produce data visualization, data analytics.	IoT prototype connecting sensor to gateway and to Cloud service and produce data visualization, data analytics.
Languages	English	English	English

In addition to these two paths, the Hackathon Playbook can be leveraged by existing IoT programs to design and conduct their hackathons, with access to the Cisco Prototyping Lab and best practices based on years of experience.

Lab Equipment and Software Requirements

The Cisco Prototyping Lab consists of the Prototyping Lab Application software that is provided for free to the Academy students and the Prototyping Lab Kit that Academies will need to purchase. Instructors may substitute the recommended list of sensors and controllers with other similar devices based on the price and availability in their region, and would then need to customize the lab and activities accordingly.

The Prototyping Lab Application runs on Microsoft Windows and Mac OS and supports labs on the Raspberry Pi 3 in the Prototyping Lab Kit. Cisco Packet Tracer activities are designed for use with Packet Tracer 7.1 or later. Each team of 2-4 students needs one Prototyping Lab Kit used across the three courses as follows:

Connecting Things

- Raspberry Pi 3 CanaKit Ultimate Starter Kit
- Sparkfun Inventor's Kit for Arduino - V3.2
- Multicolored Jumper Wires: 40-pin Male to Female, 40-pin Male-to-Male, 40-pin Female-to-Female
- Breadboard Jumper Wires

Big Data & Analytics

Connecting Things equipment list plus:

- Raspberry Pi Camera Module v2

Hackathon Playbook

- Required: Connecting Things and Big Data & Analytics equipment list
- Recommended: Instructors may add other sensors and actuators to expand the creativity opportunities

A detailed listing of the lab components is in the appendix in this document for instructors to more easily use and adapt existing and regionally-equivalent equipment in their classrooms.

Instructor Training Requirements

The IoT Fundamentals curriculum requires instructor training. Instructor training can be delivered by ITCs in person and/or online. Instructor training and accreditation is also achievable by a self-paced online course that will be available to register for at General Availability on Netacad.com. Several Instructor Fast Track options will be available, including all instructors who actively participated in the IoT Fundamentals Small Market Trial, Limited Availability, and course authoring instructor engagements.

These requirements are subject to refinement.

Course Pre-requisite Knowledge

Recommended pre-requisite knowledge for Connecting Things:

- Basic TCP/IP networking including cabling and connecting devices in a LAN and to the Internet.
- Familiarity with Cisco Packet Tracer, a network and IoT devices simulation application.
- Experience using any programming language to solve basic algorithmic problems.
- Foundational knowledge of physics including current, voltage, resistance, and power.

IoT is an interdisciplinary domain, for this reason, although not mandatory, student learning will be maximized if the students have completed one or more of the following Networking Academy courses:

Networking: Networking Essentials or CCNA-Introduction to Networks or IT Essentials

Programming: Python Essentials, releasing within the next 6 months

Security: Cybersecurity Essentials

IoT Fundamentals: Connecting Things Course

In this course, students will explore the three basics insights of the Internet of Things: Why do we want to connect everything? What do we want to connect? And how do we connect everything?

A typical IoT solution includes sensors, local analytic abilities, network connections, and the ability to process and analyze the gathered data. Overall, it is important to understand how a product or a process or a business can be improved with the instrumentation and the collection of data. It all starts with the end-to-end interconnection from a sensor to a gateway and from there to the network and the cloud.

Students who complete Connecting Things will be able to perform the following:

- Create circuits and microcontroller programs with the Arduino and a variety of components.
- Create Python programs on the Raspberry Pi to provide IoT functionality.
- Use Packet Tracer to model Python-based IoT systems.
- Diagram a business model using the Business Model Canvas.
- Explain how the IoT can be used to provide solutions in healthcare, energy, smart-city, and manufacturing.
- Explain the importance of designing IoT solutions that secure and protect devices, software, and data.

Table 3. IoT Fundamentals: Connecting Things Course Outline

Chapter	Connecting Things	Summary Description
1	Things and Connections	Understand the building blocks, interconnections and information flow of an IoT System.
2	Sensors, Actuators, and Microcontrollers	Use sensors and an Arduino microcontroller to read data from the physical world and control actuators.
3	Software is Everywhere	Use Python to program a Single Board Computer (Raspberry Pi) to perform more complex embedded programs.
4	Fog Networks and Cloud Services	Learn the principal IoT Networking Protocols. Learn how an IoT system distributes computing between Fog and Cloud networks. Learn how to interconnect systems using Restful APIs.
5	Industrial IoT Applications	Learn how IoT technologies are applied in diverse vertical markets: Healthcare, Smart Cities, Smart Grid, and Manufacturing.
6	Create an IoT Solution	End-to-end case study on how to create an IoT Prototype.

IoT Fundamentals: Big Data & Analytics Course

The Internet of Things increases the opportunity for people to create and invent new devices, due to lower costs and greater access. The resulting explosion of new types of devices and solutions further contributes to the explosion of data in the IoT. Organizations are now critically dependent on the collection, storage and analysis of this data to extract information and insight for the business. The virtualization of devices, networks, and data is a trend that will continue to impact the design and implementation of data center technologies. Making good decisions depends on good data. As the amount of data grows exponentially, decision makers increasingly rely on data analytics to extract the required information at the right time and in the right place to make the best decision.

Students entering the Big Data & Analytics course are expected to have already completed the Connecting Things course or equivalent. In addition, these students are also expected to have more solid experience in writing and debugging Python code.

Students who complete the Big Data & Analytics course will be able to perform the following functions:

- Explain how businesses can extract information and insights from IoT Data.
- Understand the steps of the Data Analysis Lifecycle and perform these tasks.
- Explain the different types of data analytics: descriptive, predictive, and prescriptive.
- Use Python to create a data pipeline to acquire, manipulate and visualize sensor data.
- Apply exploratory data analysis to extract insights from data.
- Understand the application of machine learning.
- Present and communicate using data storytelling.
- Describe the evolution of data management technologies from SQL to NoSQL.
- Understand and explain the evolution of a modern data center computing platform and the distributed scalable Big Data platform like Apache Hadoop.

Table 4. IoT Fundamentals: Big Data & Analytics Course Outline

Chapter	Big Data & Analytics	Summary Description
1	Data and the Internet of Things	Understand the concepts of Big Data and Analytics, and the role of Big Data in IoT systems.
2	Fundamentals of Data Analysis	Learn the basics of descriptive statistics, the practical aspects in acquiring data from a sensor and how to create visual representations of the data.
3	Data Analysis	Explore data using visualization to extract information and create hypotheses.
4	Advanced Data Analytics and Machine Learning	Learn about predictive analytics, the supervised and unsupervised approaches to machine learning and how to apply models to make predictions from the data.
5	Storytelling with Data	Learn how to transform analytics results into a clear and convincing narrative and visual communication.
6	Architecture for Big Data and Data Engineering	Learn the basic principles behind the most important scalable solutions for Big Data such as Apache Hadoop and the related ecosystem of technologies.

IoT Fundamentals: Hackathon Playbook Course

A Hackathon is an event where multiple teams work uninterrupted within a limited timeframe (usually 24-30 hours) to ideate, prototype, and present a solution to the proposed challenge.

The Hackathon Playbook is a guide on how to use a combination of tools to effectively prepare for and run a hackathon. It is based on the best practices and lessons-learned collected from the global execution of numerous IoT hackathons within the Networking Academy and by other hackathon organizers.

Students who complete the IoT Hackathon will be able to perform the following functions:

- **Inspiration**: understand, select and present the problem to be solved and to recruit fellow partners.
- **Ideation**: invent an original concept to solve a social issue. Learn how to present the solution to experts who are going to help them prototype.
- **Prototyping**: create a prototyping action plan, including objects and visuals to illustrate their words, and that will help an expert understand the concept and prototyping needs.
- **Testing**: present the concept and validate the prototype with a second expert, including user experience and enhancements.
- **Presentation**: present the solution and demo the prototypes to an expert panel.

Students will apply the skills that they have learned in the Connecting Things and Big Data & Analytics courses in the hackathon. They will be working in teams, ideally interdisciplinary teams, and in the process deepening their development of 21st century skills such as Creativity, Communication, Collaboration and Critical Thinking.

Appendix: Detailed list of materials for the Prototyping Lab Kit

Raspberry Pi 3

uUSB Power Adapter (PSU) with min 2A power
uSD card at least 4GB
USB uSD card reader
SparkFun Redboard (Arduino UNO compatible board)
10x 330Ohm resistor
10x 10kOhm resistor
3x red LED
3x green LED
3x blue LED
1x RGB LED
1x 10kOhm potentiometer
1x relay
1x transistor
1x photoresistor
1x bending sensor
…
40x male-male jumper cables
40x male-female jumper cables
Female miniUSB to USB cable
…