Networking Academy

IoT Fundamentals

Curriculum Scope and Sequence

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Introduction

Cisco Networking Academy's IoT Fundamentals curriculum provides students with a comprehensive understanding of the Internet of Things (IoT). It develops foundational skills using hands-on lab activities that stimulate the students in applying creative problem-solving and rapid prototyping in the interdisciplinary domain of electronics, networking, security, data analytics, and business. The student-centric approach translates into the student being able to ideate, design, prototype and present an IoT solution for an identified business or society need.

The interconnection of previously unconnected devices to the internet and the analysis of the data they generate are having a disruptive and transformational effect 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 mined to gain insights or automate smart behaviors. The exponential growth of data is increasing the demand for professionals with the skills to work on this ocean of data. IoT, 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[2], 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.

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

Using this interdisciplinary approach, the IoT Fundamentals curriculum aims to equip students with a Global Problem Solver mindset and skillset, and to fuel their imagination through a deeper understanding of the transformative impact IoT, Big Data, and analytics technologies are having on business and our ability to solve social issues.

Target Audience

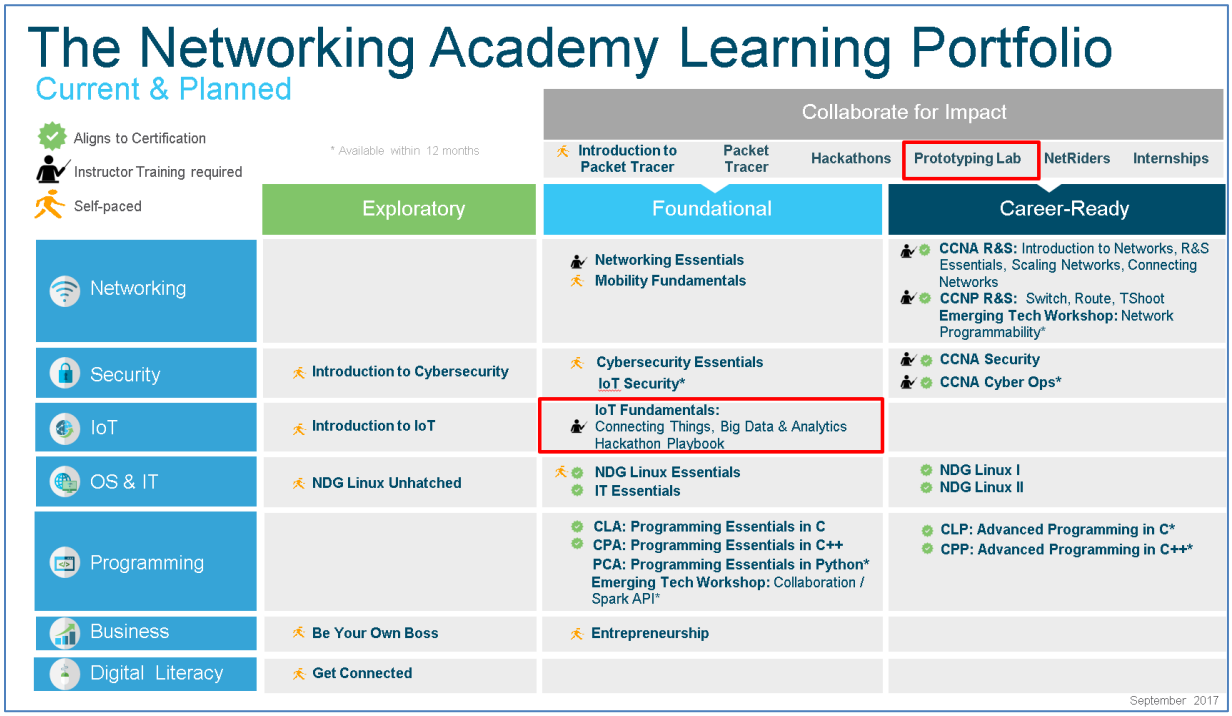
The IoT Fundamentals curriculum is designed for Cisco Networking Academy® students who are seeking to acquire the foundational skills and knowledge prominently required across the emerging digitization technologies using a hands-on, problem-solving approach. The IoT Fundamentals curriculum has been designed to be flexible in order to adapt appropriately for students at many education levels and types of institutions. It has already been favorably tested in secondary schools, career and technical schools, universities, and colleges, and is included as coursework in planned new technical university IoT-related curriculum in some countries.

Government workforce retraining initiatives, strategic workforce planning initiatives, military, Maker spaces, and community-based training centers will also likely find value in this curriculum.

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 common basis for multiple Career-Ready learning paths. In the fast-changing world of IoT, it is most critical for our Networking Academy students to focus on the technical and soft skills that are common across many career specializations.

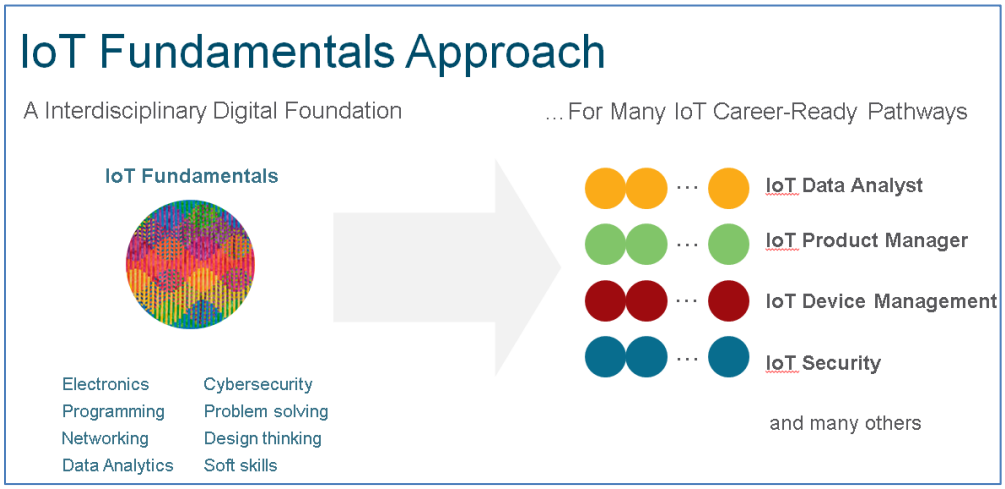
Figure 1. IoT Fundamentals is a Foundational curriculum within the NetAcad Learning Portfolio



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.[3] Figure 2 illustrates how IoT Fundamentals provides the interdisciplinary foundational skills needed for the many different IoT Career-Ready learning paths emerging in the job marketplace today.

Figure 2. IoT Fundamentals' interdisciplinary 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 and extraction of insights through data analysis, and
- 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. One of the consistent instructional focus areas across the IoT Fundamentals curriculum is to develop and expand a creative "Maker" mindset. Students tinker, prototype, and iterate in a lab environment modeled after "Maker Spaces" and then transition to understand how those concepts can be applied at the Enterprise level to transform businesses.

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 (Raspberry Pi, Arduino), a customized interactive Python programming interface, and Enterprise-grade technologies (Cisco Spark).

[3] SkillZone pilots http://csr.cisco.com/skillzone

- 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 thus far. In the hackathon they will work in a team to identify a business or social need, design a prototype of a solution to address the identified need, and present 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 reinforce understanding and help visualize the concepts.

This highly engaging curriculum encourages and excites students to consider continuing their education to specialize 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
Required Instructor Training	Yes	Yes	No
Instructional Hours	40-50 hours	40-50 hours	Recommend 20-30 hours distributed on 3 days, but flexible
Instruction Model	Instructor-led	Instructor-led	Instructor-led

There are two key concepts in creating any Internet of Things solution: Connect the Unconnected and then transform the data provided by these 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.

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 (Cisco Packet Tracer).
- Design and prototype IoT solutions using electronics, microcontrollers (Arduino) and single board computers (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 (Cisco Spark).
- 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).

This path provides only a basic comprehension of data analytics; however, at this level the students are not expected to apply this knowledge within a Hackathon.

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 on data analytics and Big Data systems. It includes extensive hands-on labs to practice data acquisition from sensors and video cameras, data visualization and an introduction to Machine Learning. This path enhances the communication skills and business acumen of the students by teaching storytelling with data. It introduces the students to the field of Big Data engineering platforms. The capacity to leverage the data analytics in the 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 familiarity with programming, 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 (Packet Tracer).
- Design and prototype IoT solutions using electronics, microcontrollers (Arduino) and single board computers (Raspberry Pi).
- Use Python to Collect, Transform, analyze, and visualize data from the sensor and store them in SQL data bases.
- Conduct exploratory data analysis activities.
- Apply basic Machine Learning algorithms to extract insights from data.
- Present and communicate using data 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 the 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 summarizes the features of these recommended learning paths, including a compressed version of the Connections into Insights paths for 4-year engineering programs.

Table 2. Features of recommended learning paths

Feature	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: Connecting Things + Hackathon (70)	1st semester: Connecting Things + Hackathon (70) 2nd Semester: Big Data & Analytics + 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.

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; in that case it will be their responsibility 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. Each team of 2-4 students needs one Prototyping Lab Kit used and added to across the three courses as follows:

Connecting Things

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

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 kits and components is available on the Cisco Prototyping Lab Resources page.

Cisco Packet Tracer activities are designed for use with Packet Tracer version 7.0 or later as follows:

- IoT Fundamentals 2.0 uses PT 7.0
- IoT Fundamentals 2.0.1 uses PT 7.1

Instructor Training Requirements

The IoT Fundamentals Connecting Things and Big Data & Analytics courses require instructor training. Accreditation can be achieved in two ways: via traditional ITC training or via a self-paced training course. Cisco Academies should consult their ASC about the most appropriate training options based on the instructor candidate's background and location for each IoT Fundamentals course they plan to teach. Each IoT Fundamentals course has a distinct and unique skillset needed to successfully teach the course. Please refer to the IoT Fundamentals Course Resources page for more details.

Instructor professional development (IPD) on the Hackathon Playbook is highly recommended for people who have never organized and facilitated a hackathon. Instructors can join relevant sessions during the TFE team's Global IPD Week to learn more about the IoT Fundamentals courses and to develop skills to effectively organize and facilitate hackathons. Experienced ASC Academies and ITC Academies may also provide professional development on Hackathon Playbook to Cisco Academy instructors.

Course Pre-requisite Knowledge

Recommended pre-requisite knowledge for Connecting Things:

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

It is important to highlight that 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 or equivalent courses:

- Networking- Networking Essentials or CCNA-Introduction to Networks or IT Essentials
- Programming- PCA: Programming Essentials in Python (coming soon)
- 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 overall can be improved with the instrumentation and the collection of data. It all starts with the connection of 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 security aspects of IoT solutions.
- Explain how the IoT can be used to provide solutions in healthcare, energy and smart-city and manufacturing.

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 exponential growth of data in the IoT. Organizations are now critically dependent on the collection, storage and analysis of this data to extract information and gain insights for the business. Making good decisions depends on good data. As the amount of data grows, 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.
- Understand privacy and security aspects of data.
- 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 how Machine Learning algorithms can be used for predictive analytics.
- 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 be aware of distributed scalable Big Data solutions such as Apache Hadoop, Cassandra and Spark.

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 & 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 statistics and visualization to extract information and create hypotheses.
4	Advanced Analytics & 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	Introduction to Data Center & 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

A hackathon is an event where multiple teams work uninterrupted within a limited timeframe (usually 24-30 hours) to ideate, iteratively 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 an IoT Fundamentals hackathon as guided in the Hackathon Playbook 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 business or 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 multidisciplinary teams, and in the process deepen their development of 21st century skills such as Creativity, Communication, Collaboration and Critical Thinking.