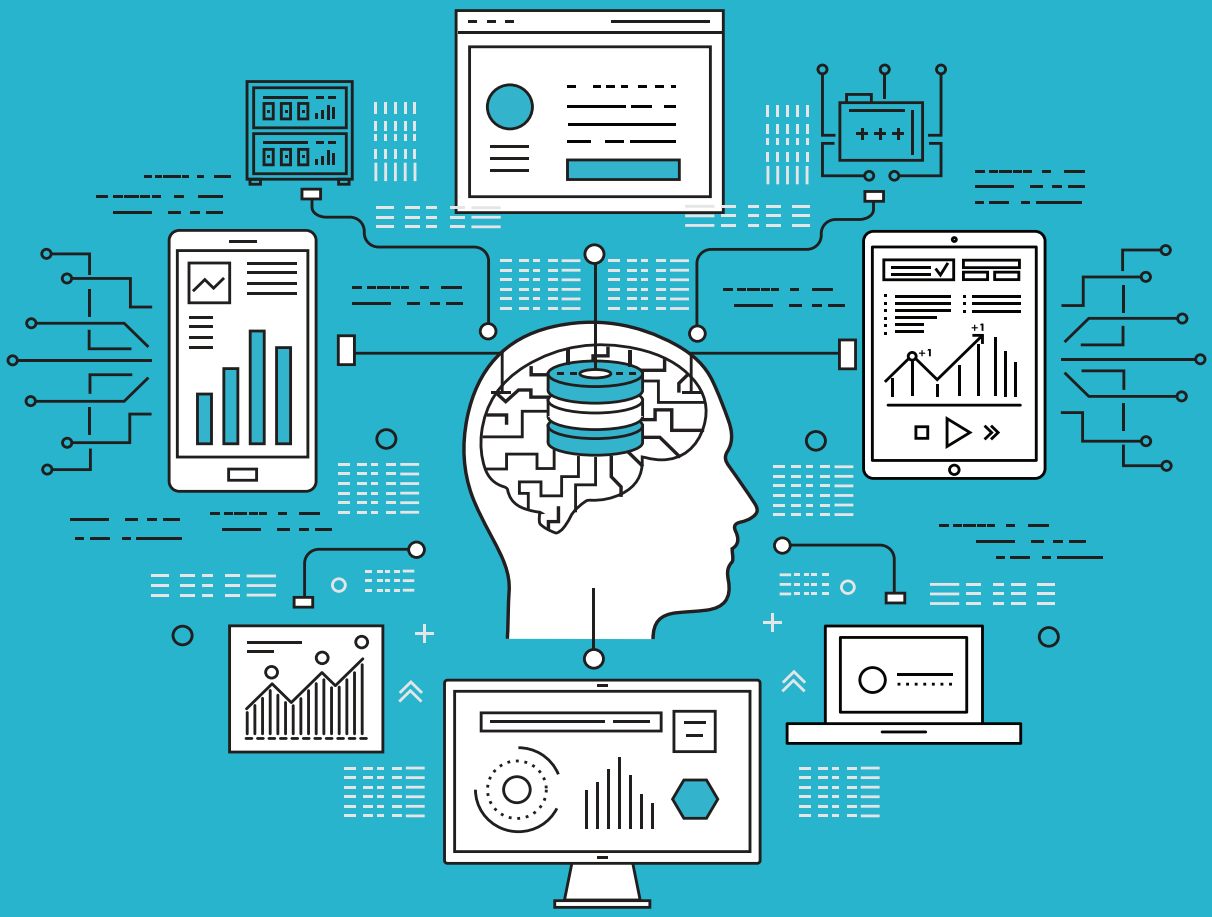
COMPUTING DISCIPLINES



A QUICK GUIDE FOR PROSPECTIVE STUDENTS AND CAREER ADVISORS

RANDY CONNOLLY & JANET MILLER & FAITH-MICHAEL UZOKA

ACKNOWLEDGMENTS

This guide builds on findings from a CERIC-funded international research project and computing curricula reports created by the ACM.

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Charts on pages 10, 14, 18, 22, and 26 are based on those that appear in the ACM Computing Curricula 2005 report.

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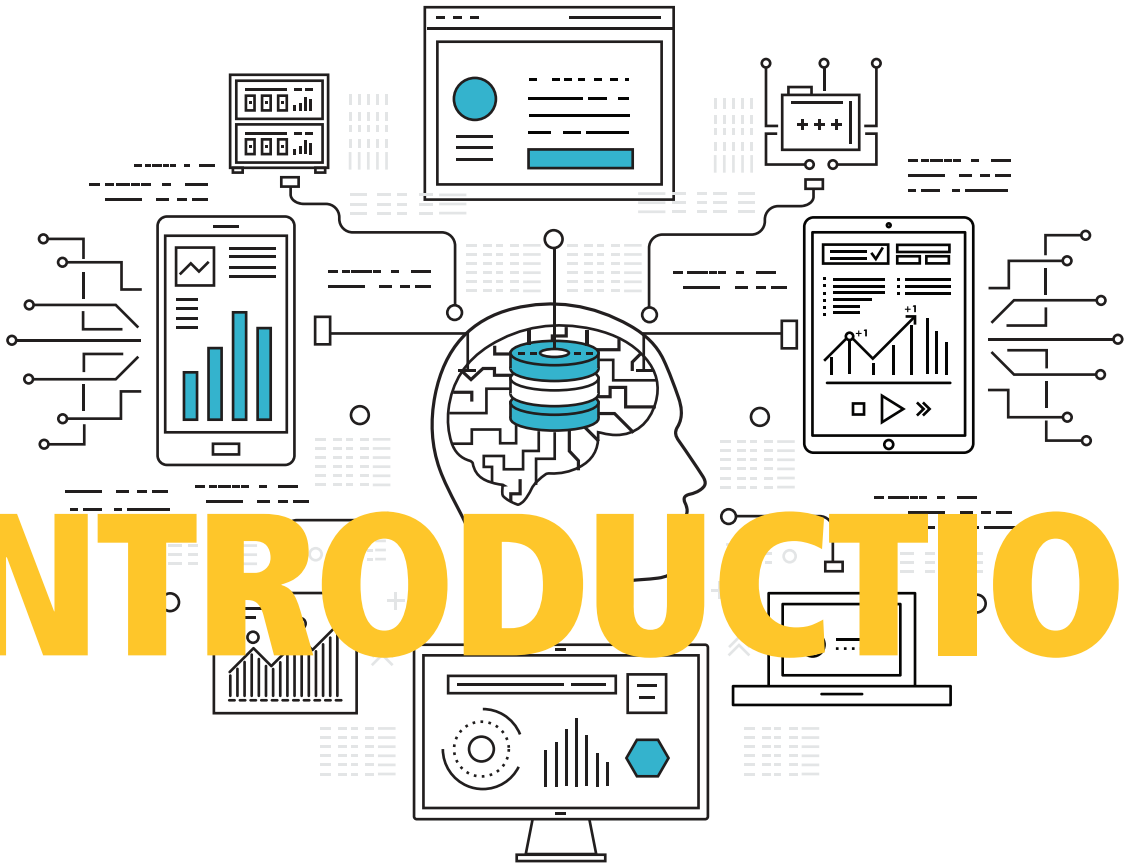
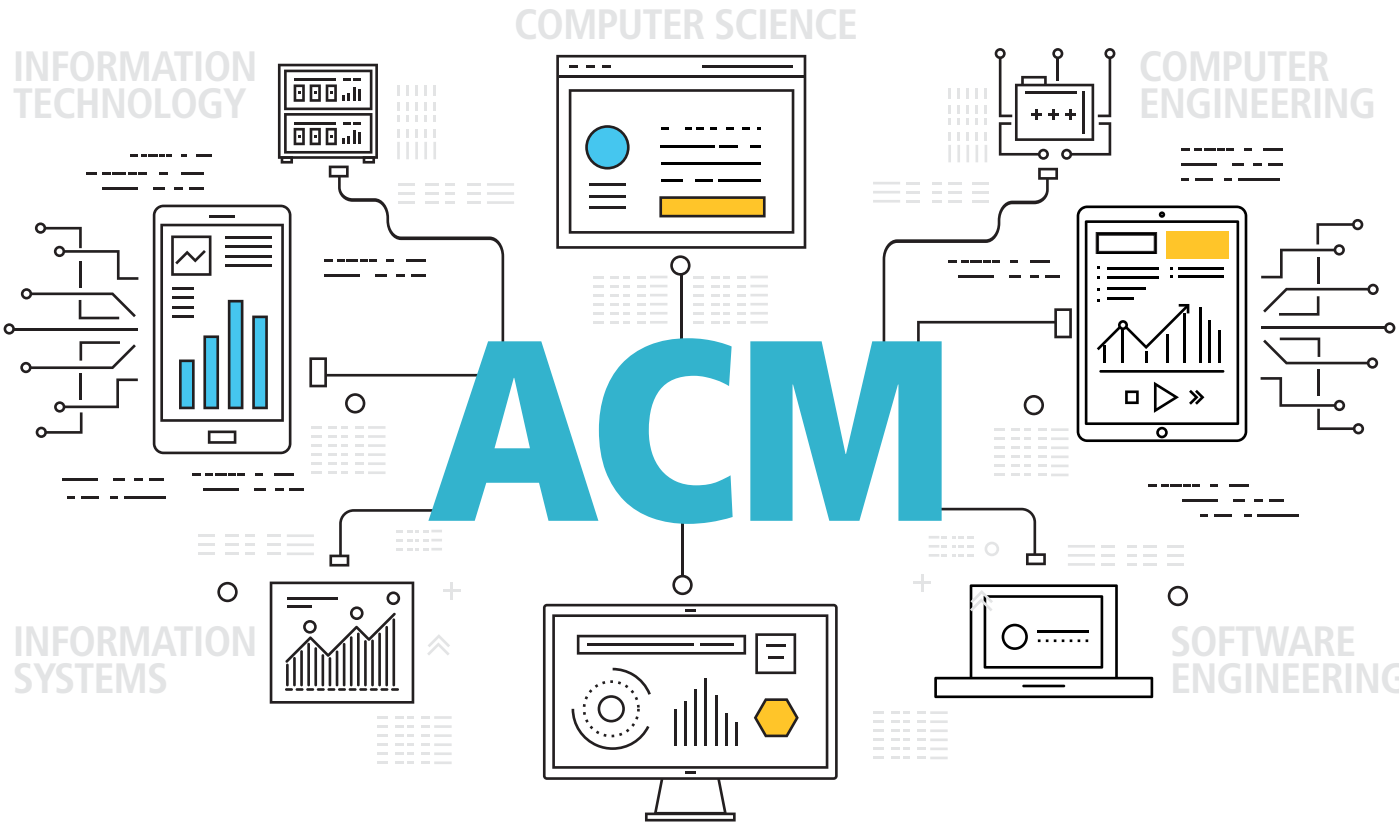


INTRODUCTION

The field of computing has expanded rapidly over the past ten years, and after surveying thousands of students from Canada, the USA, and Africa, we realized that students need more information about this field and its related careers.

This Guide is designed to outline the five computing disciplines, and show how they relate to specific job titles and tasks.

Information about additional training and specializations are also provided along with links to Canadian occupational information resources. For more information on how to design your career, we recommend resources available on the CERIC website (*www.ceric.ca*).



Many career-counselling web resources do not list all the computing disciplines as identified by the ACM (Association of Computing Machinery), but instead treat computing as a single discipline, typically computer science.

But in reality there is not a single computing discipline but at least five. Including different sub-specialities, there are dozens of possible computing educational paths for prospective students.

The ACM has outlined **five** distinct computing disciplines: computer science, computer engineering, information systems, information technology, and software engineering.

While ACM curricula is oriented towards degree programs, many computing certificates and diplomas borrow from or blend these disciplines together.

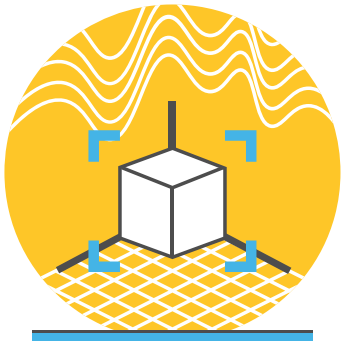
Students, advisors, and career counsellors need more information to better understand what each one of these computing disciplines does and which best suits their interests, talents, skills and abilities.

This guide is designed to support prospective students, career practitioners, academic advisors and career counsellors by outlining these five areas of practice and providing information you can use to guide interested students.

COMPUTING DISCIPLINES

The ACM has identified five computing disciplines, as well as mixed majors combining computing with other areas of expertise.

This Guide provides an overview of each of these disciplines, and their related careers, core courses, key tasks and sample jobs.

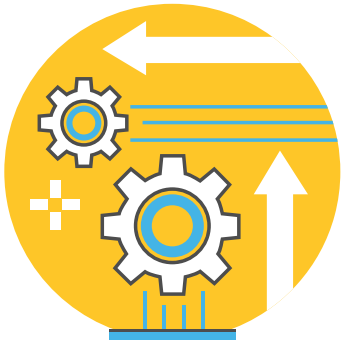


COMPUTER ENGINEERING

COMPUTER SCIENCE

INFORMATION SYSTEMS

INFORMATION TECHNOLOGY



SOFTWARE ENGINEERING

OTHER SPECIALIZATIONS

DISCIPLINE ROADMAP

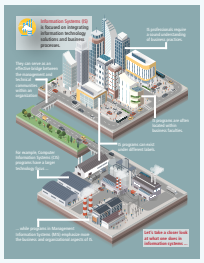
TO HELP EXPLAIN THE DIFFERENCES IN THE COMPUTING DISCIPLINES, THIS GUIDE USES A CITY METAPHOR. EACH DISCIPLINE HAS ITS OWN CITY DISTRICT THAT PROVIDES AN OVERVIEW OF THE DISCIPLINE AND THEN STEPS INSIDE THAT DISCIPLINE TO DESCRIBE TYPICAL JOB TASKS.

COMPUTER ENGINEERING (CE)

is concerned with the design and construction of computers and computer-based systems.

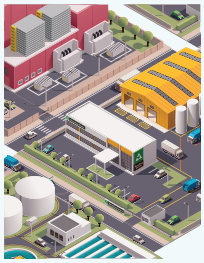
INFORMATION SYSTEMS (IS)

is focused on integrating information technology solutions and business processes.



SOFTWARE ENGINEERING (SE)

is the discipline of developing and maintaining large software systems.

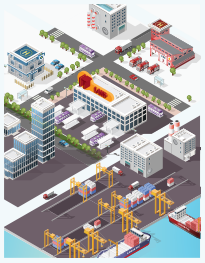


COMPUTER SCIENCE (CS)

covers the widest range of computing topics from its theoretical foundations to the development of new computing technologies and techniques.

INFORMATION TECHNOLOGY (IT)

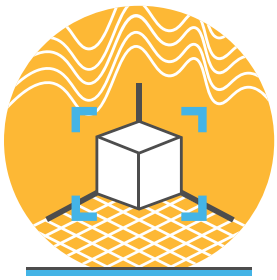
programs prepare students to meet the computer technology needs of business and other organizations.

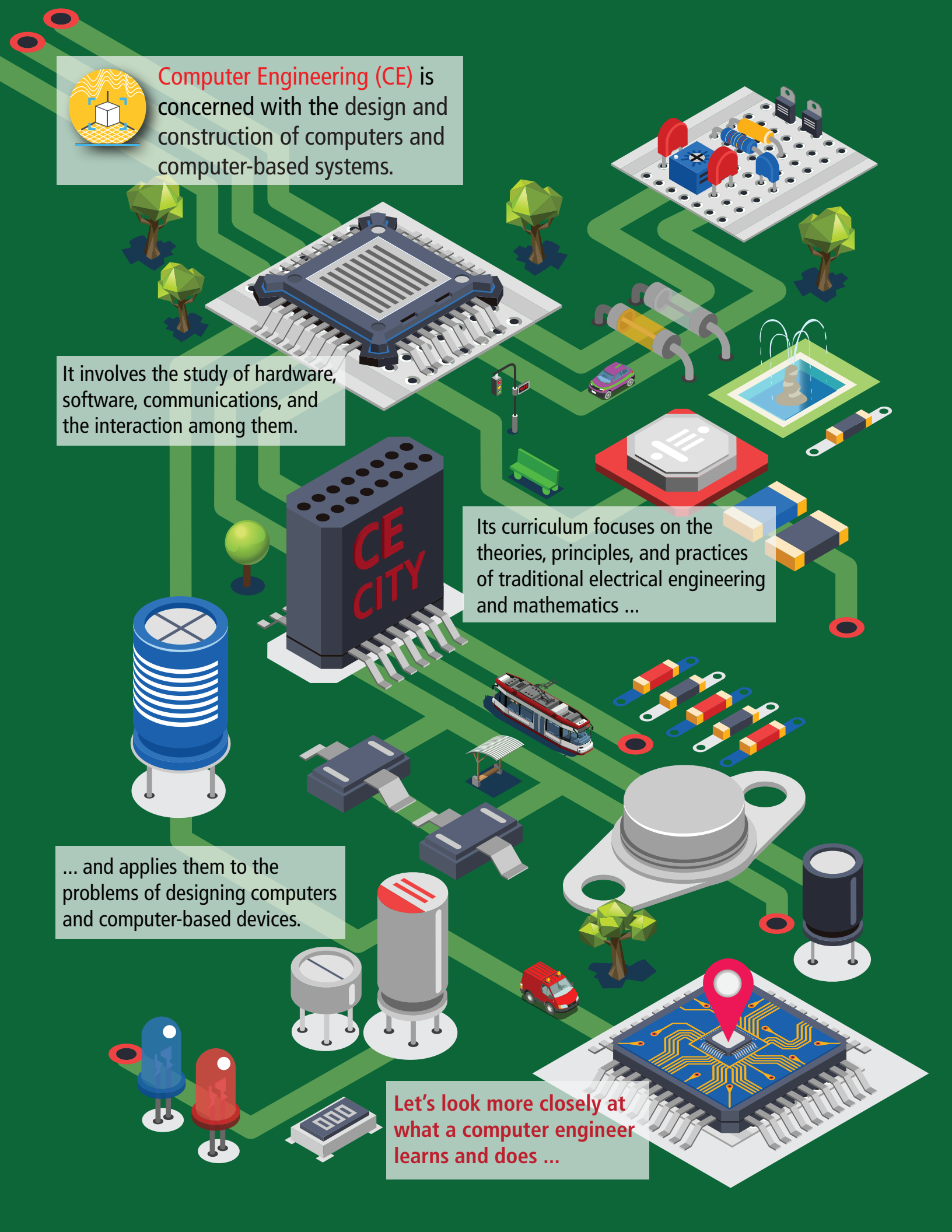


COMPUTER ENGINEERING

Computer Engineers are focused on the **connection between hardware and software**. A dominant area within computing engineering is embedded systems: the development of devices that have software and hardware embedded in them. Devices such as cell phones, digital audio players, digital video recorders, alarm systems, x-ray machines, and laser surgical tools all require integration of hardware and embedded software.

The emphasis here is more on hardware than on software, but CEs use both for integrated devices. CEs apply engineering theories to the problems of designing computers and computer-based devices. This is a theory-driven practice which incorporates traditional engineering and mathematics.



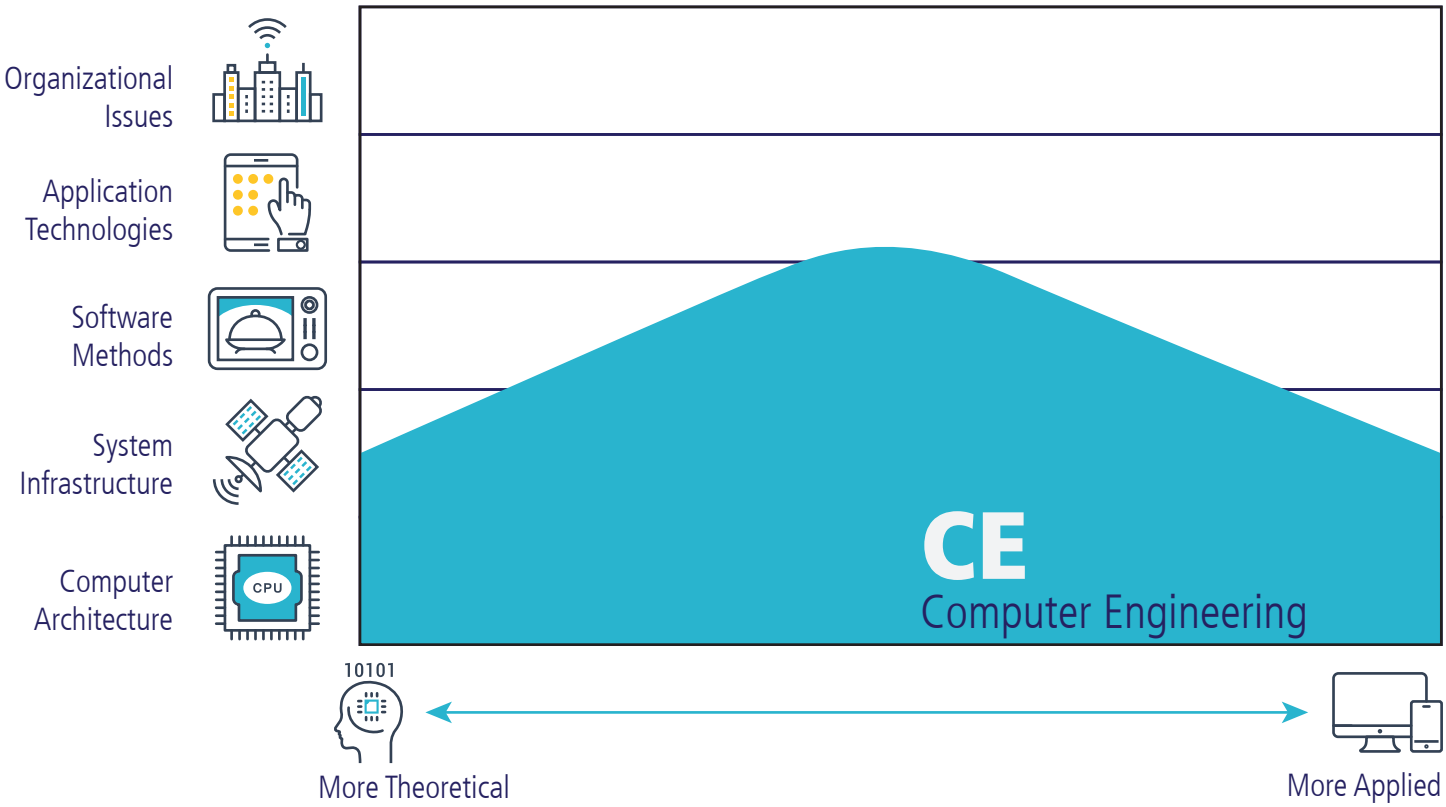

Computer Engineering (CE) is concerned with the design and construction of computers and computer-based systems.
It involves the study of hardware, software, communications, and the interaction among them.
CE CITY
Its curriculum focuses on the theories, principles, and practices of traditional electrical engineering and mathematics ...
... and applies them to the problems of designing computers and computer-based devices.
Let's look more closely at what a computer engineer learns and does ...


Computer Engineering
In Computer Engineering (CE), we are especially interested in the interaction between hardware and software.
We develop embedded systems, that is, devices with software and hardware in them.
We help design 3D printers, cell phones, robots, control systems, and many other digital devices.
INSIDE CE
We are also engineers, which means we also have traditional engineering skills and training.
We study project management, testing, process control, mathematics, signal processing, and other topics.
We develop software as well, typically with a focus on the hardware-software interface.
Interesting ... we do some of these same tasks over in Computer Science but are more focused on the software aspects.
In Information Technology, we are also interested in hardware but in a more applied way.
CS
IT

COMPUTER ENGINEERING

Summary

Computer Engineering is focused on computer architecture and infrastructure, from the applied to the theoretical aspects. It also has an interest in software methods (programming) insofar as it applies to the hardware side of computing.



On the Job

Designs hardware to implement communication systems.

Develops hardware devices that are software-controlled, such as iPods, smart phones and gaming devices.

Focuses exclusively on hardware design, including digital electronics, with less involvement in software design.

Evaluates and improves the usability (user experience) of computing systems.

Take existing equipment and adapt it for specialized use.

Core Courses

Computer Architecture and Organization

Circuits and Electronics

Data Structure and Algorithms

Digital Design

Embedded Systems

Computer Networks

Signal Processing

Software Design

Information Security

Sample Programs

University of Western Ontario, Bachelor of Engineering Science in Computer Engineering

University of British Columbia, Bachelor of Applied Science in Computer Engineering

University of Alberta, Bachelor of Engineering in Computer Engineering

McGill University, Bachelor of Engineering in Computer Engineering

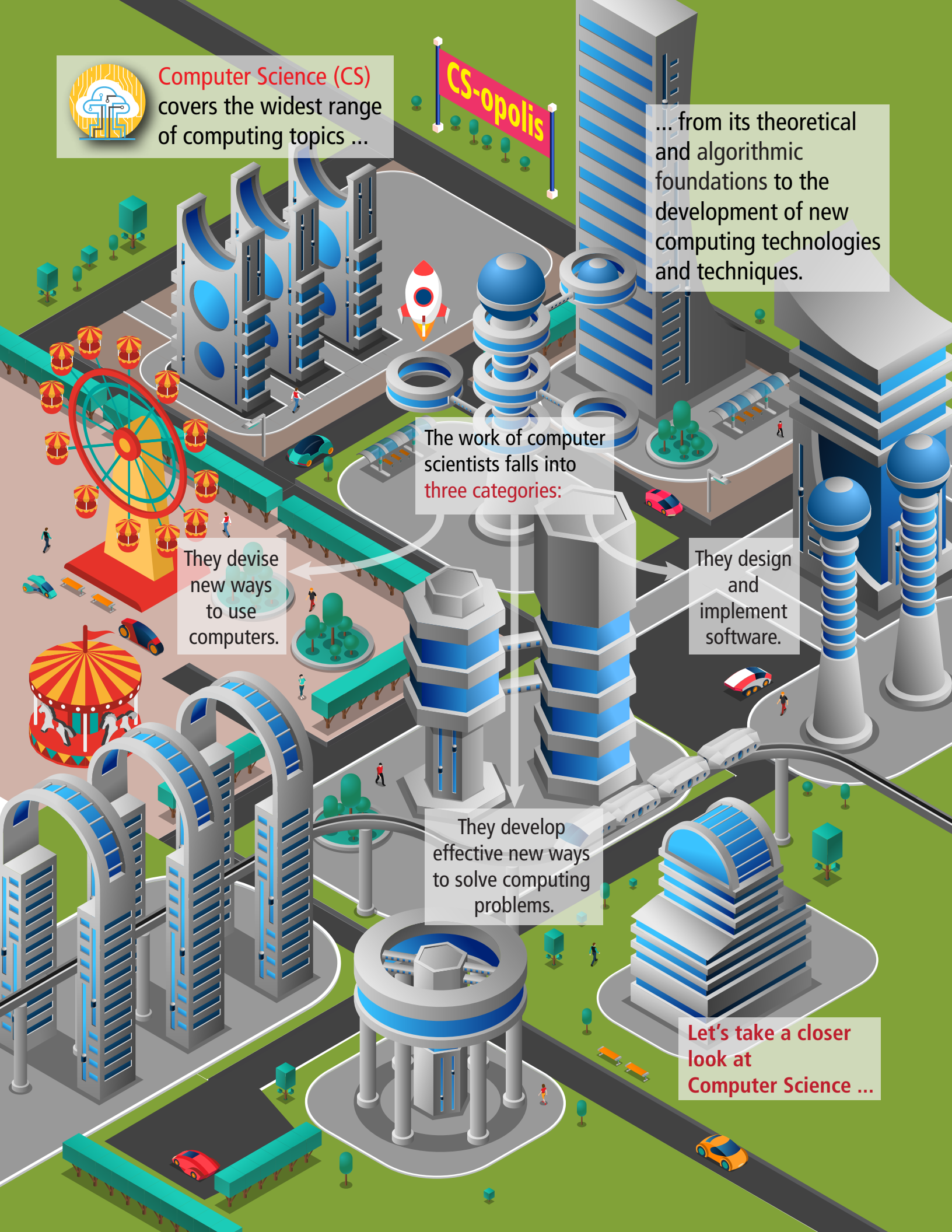
University of New Brunswick, Bachelor of Science in Computer Engineering

Seneca College, Computer Engineering Technology Diploma

COMPUTER SCIENCE

Computer Scientists develop a **strong foundation based on mathematics and algorithms**. They are trained to discover the best solutions for new problems, generate new technologies and come up with innovative cutting-edge ideas. They design and test software that applies theory to practice, creating innovations in fields like robotics, computer vision, intelligent systems and bio-informatics.

Computer Scientists think up new ways to use computers, explore applications and develop effective ways to solve complex computing problems. They are involved in computer programming, and may supervise programmer teams. Computer Scientists may also develop encryption and other data protection schemes. They are involved in large software development projects.

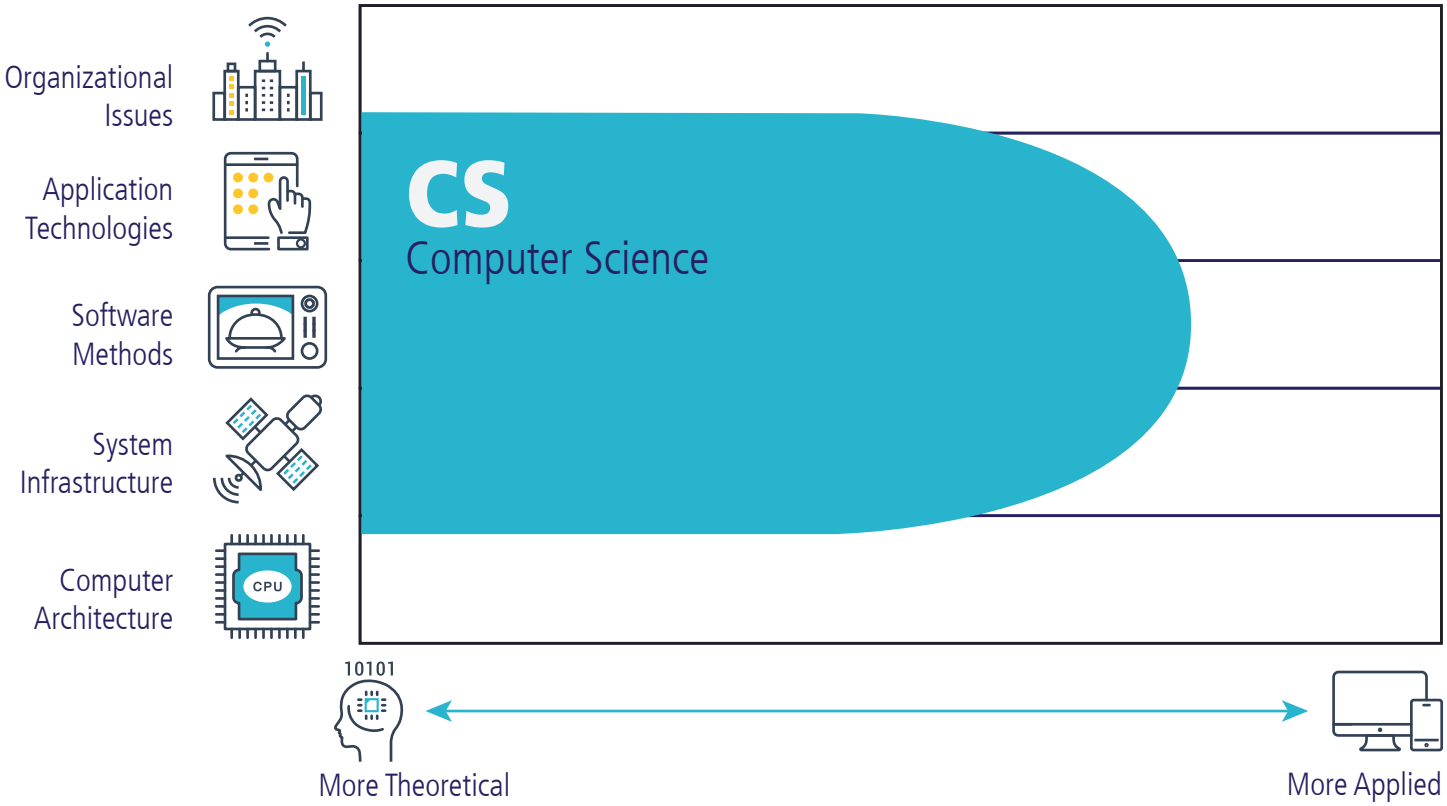

Computer Science (CS) covers the widest range of computing topics ...
CS-opolis
... from its theoretical and algorithmic foundations to the development of new computing technologies and techniques.
The work of computer scientists falls into three categories:
They devise new ways to use computers.
They design and implement software.
They develop effective new ways to solve computing problems.
Let's take a closer look at Computer Science ...


Computer Science
Computer Science (CS) professionals can perform many different tasks.
We use mathematical approaches to invent and improve new algorithms.
We take on challenging programming jobs.
Progress in CS enables innovation in other fields, such as ...
We can supervise other programmers.
... bio-informatics
... robotics
... data visualization
Our skills are often an essential foundation for games development.
In Software Engineering, we do some of these things, but more focused on the process of improving how software is created.
SE
In Information Technology, we are also generalists but are more engaged on the practical applied side.
IT
Computer Engineering has some similarities, but we are more focused on the connection between software and hardware.
CE

COMPUTER SCIENCE

Summary

Computer science has the widest range of computing topics. It focuses especially on the theoretical aspects of computing, leaving the more applied topics (and organizational and architecture issues) to other disciplines.



On the Job

Use new theories to create cutting edge software.

Focus on the theoretical aspects of technology.

Utilize theory to research and design software solutions.

Use a wide range of foundational knowledgeto adapt to new technologies and ideas.

Apply mathematical and theoretical knowledge in order to compare and produce computational solutions and choose the best one.

Core Courses

Programming and programming languages

Data structures and algorithms

Graphics and visualization

Human-computer interaction

Software development fundamentals

Artificial intelligence

Networking and communications

Operating systems

Parallel and distributed computing

Sample Programs

University of Saskachewan, Bachelor of Science in Computer Science

University of British Columbia, Bachelor of Computer Science

University of Manitoba, Bachelor of Computer Science

Memorial University of Newfoundland, Bachelor of Arts in Computer Science

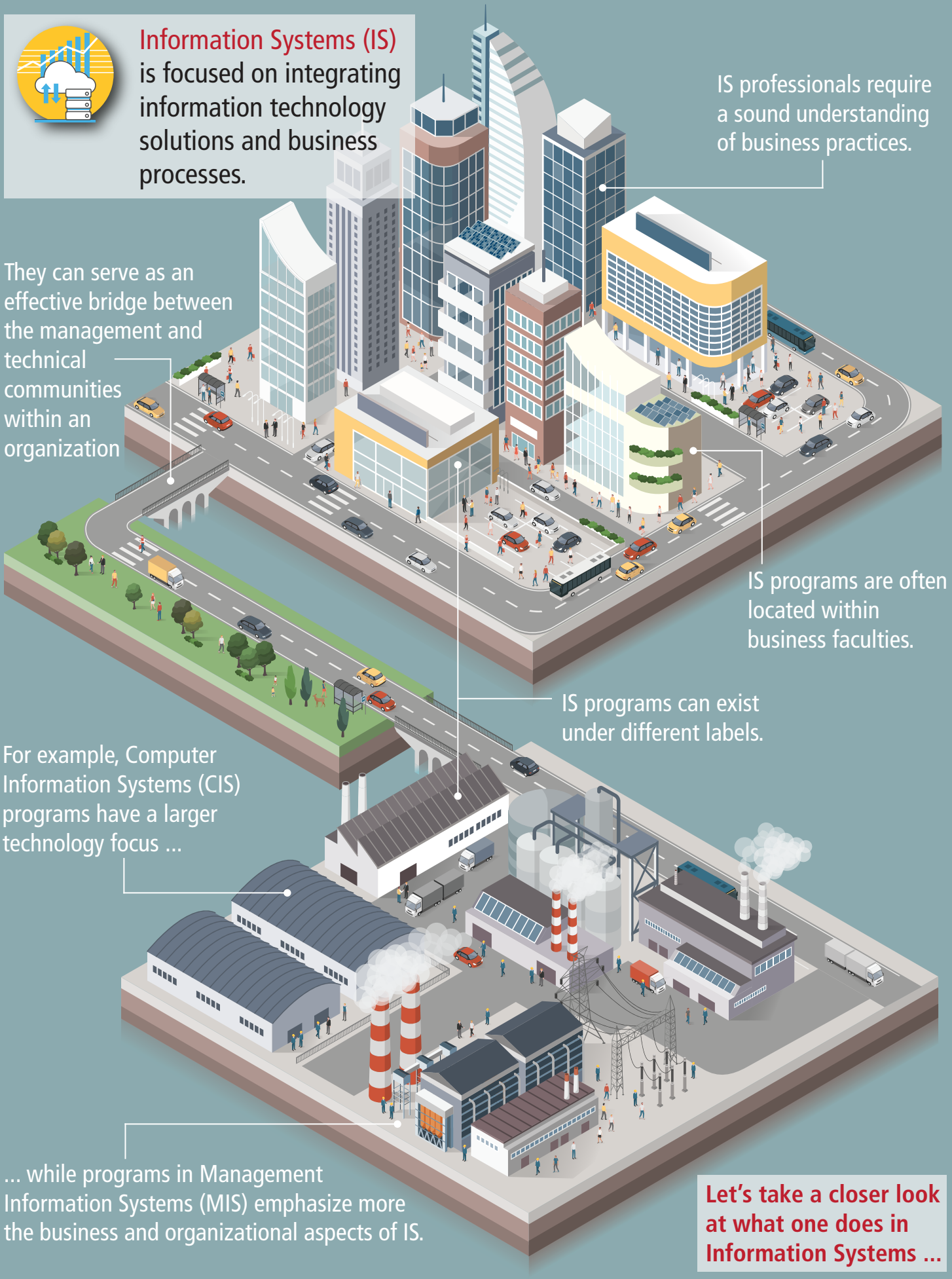
University of Prince Edward Island, Bachelor of Science in Computer Science

Dawson College, Computer Science Technology DEC

INFORMATION SYSTEMS

Information Systems specialists integrate information technology with business processes. They focus on the processing of information, and must have an understanding of how organizations and technology work.

Their studies combine business and computing coursework, and may have a computing focus or a management focus. They work closely with clients to determine how information and technology can provide a competitive advantage.

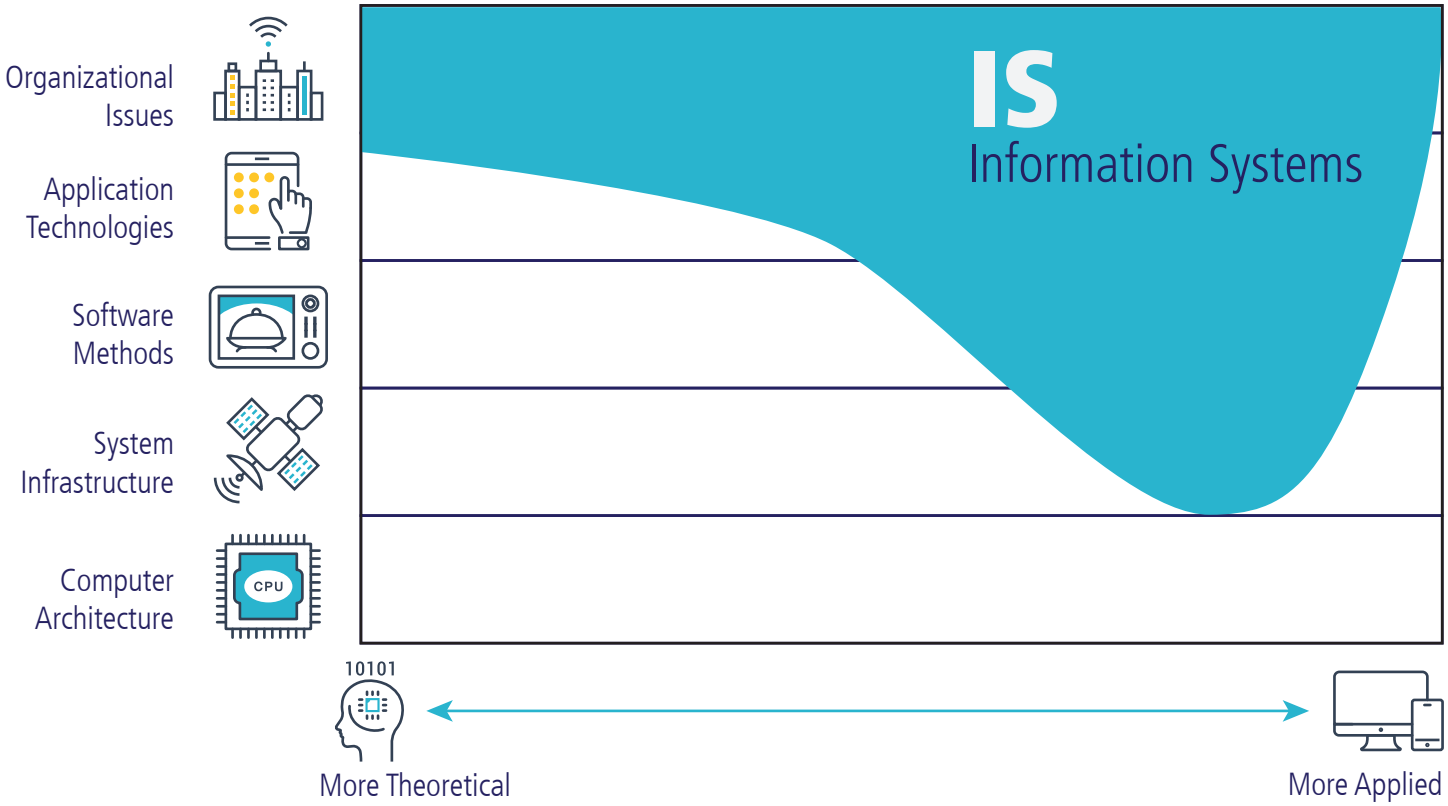

Information Systems (IS) is focused on integrating information technology solutions and business processes.
IS professionals require a sound understanding of business practices.
They can serve as an effective bridge between the management and technical communities within an organization
IS programs are often located within business faculties.
IS programs can exist under different labels.
For example, Computer Information Systems (CIS) programs have a larger technology focus ...
... while programs in Management Information Systems (MIS) emphasize more the business and organizational aspects of IS.
Let's take a closer look at what one does in Information Systems ...


Information Systems
INSIDE IS
Information Systems (IS) professionals combine business and technical knowledge.
We view technology as an instrument for generating, processing, and distributing information.
We are interested in the information that computer systems can provide to aid an enterprise in achieving its goals.
We are often the interface between the end users and the technical experts.
We can be involved in system deployment and the training of users.
We tailor application technologies (especially databases) to the needs of the organization.
Later in our career, we may manage a team of developers on a software project.
In Information Technology, we are also interested in the applied side of computing.
In Software Engineering, we manage large software projects.
SE

INFORMATION SYSTEMS

Summary

Information Systems is focused on the organizational issues of computing. Information Systems also has an interested in the applied aspects of application technologies and software development.



On the Job

Combines knowledge of business with knowledge of technology.

Selects computer systems to improve business processes.

Focuses on information, and views technology as a tool for generating, processing and distributing it.

Uses technology to give a business a competitive advantage.

Manages projects, teams of software developers or a computing department.

Core Courses

Foundations of Information Systems

Data and Information Management

Enterprise Architecture

IS Project Management

Systems Analysis and Design

Knowledge Management and Business Intelligence Systems

IS Security, Privacy and Ethics

IS Strategy, Management & Acquisition

IT Infrastructure

Sample Programs

University of Windsor, Bachelor of Science in Computer Information Systems

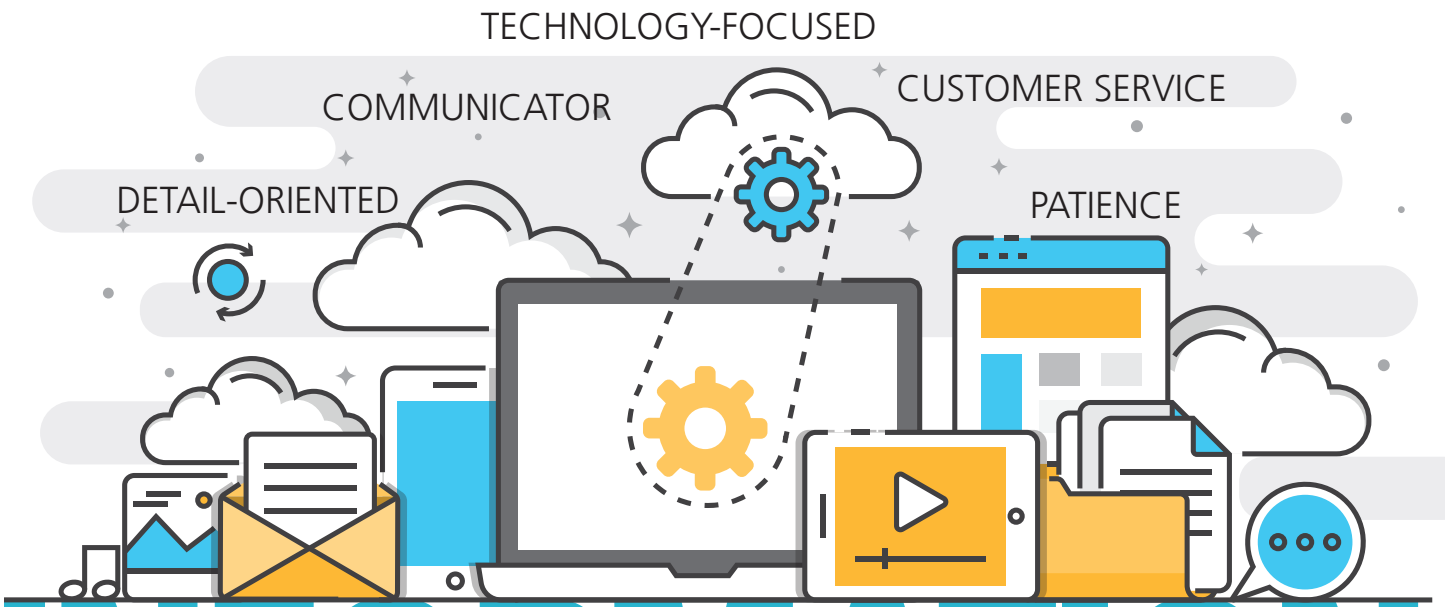
Queen's University, Bachelor of Commerce in Information Systems

Mount Royal University, Bachelor of Science in Computer Information Systems

Concordia University, Bachelor of Computer Science in Information Systems

St. Francis Xavier University, Bachelor of Information Systems

Okanagan College, Computer Information Systems Diploma



INFORMATION TECHNOLOGY

Information Technology professionals **provide customer service with a focus on technology**. They work to meet the computer technology needs of business, government, healthcare, schools, and other kinds of organizations. Their emphasis is on the technology itself more than the content or information it conveys.

IT professionals select appropriate hardware and software products for the organization, and integrate these with existing hardware. Their responsibilities may include installation of networks, security, design of web pages, multimedia resource development, and the installation of communication components such as email systems. They are responsible for planning and managing the entire technology lifecycle.

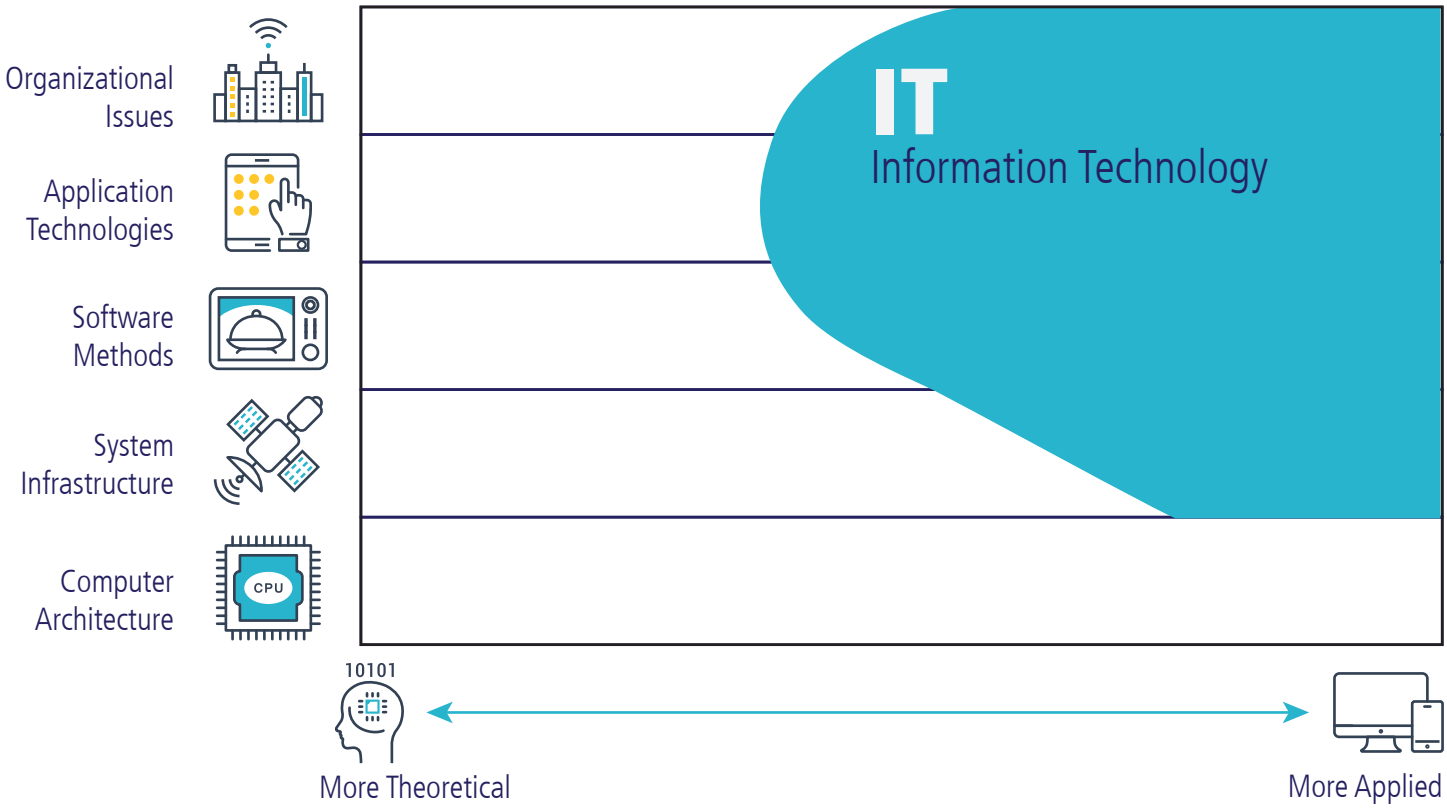

Information Technology (IT) programs prepare students to meet the computer technology needs of of business and other organizations.
POLICE
FIRE DEPARTMENT
2
IT
LAND
IT is a new field and its programs exist under different labels (that is, they may not use the IT label in their name).
IT specialists select hardware and software products and ...
... install, customize, and maintain those products for the organization's computer users.
LOGISTIC
LOGISTIC
Let's take a closer look at Information Technology tasks ...


Information Technology
In Information Technology (IT) we are principally focused on how to configure, use, and support technology infrastructures within organizations.
We understand computer systems and their software and help to solve computer-related problems.
Organizatons are dependent upon information technology and IT professionals help support it.
We also do software development, especially in applied areas such as web sites and mobile apps.
We can help configure and improve an organizations' data infrastructure.
INSIDE IT
We possess a combination of theoretical knowledge and practical, hands-on expertise.
This means we can take care of an organization's information technology infrastructure.
We install, customize, and maintain both applications and devices for an organization and its users.
In Information Systems, we are mainly interested in the business aspects of information technology.
In Computer Engineering, we are also interested in hardware, but we focus on designing and creating it.
IS
CE

INFORMATION TECHNOLOGY

Summary

Information Technology is focused on the applied side of computing. It covers all aspects of technology infrastructure, including hardware, operating systems, applications, data storage and communication systems.



On the Job

Integrates hardware and software.

Applies technology to solve practical problems.

Provides a support role, within an organization, to help others make the best use of its technical and information resources.

Uses a wide range of foundational knowledge to adapt to new technologies and ideas.

Understands both technology and business, but with a focus more on the technical side.

Core Courses

IT Fundamentals

Programming Fundamentals

Fundamentals of Networking

Information Assurance and Security

System Administration and Maintenance

IT infrastructure and Project Management

Fundamentals of Web Systems

Database Systems

Sample Programs

York University, Bachelor of Arts in Information Technology

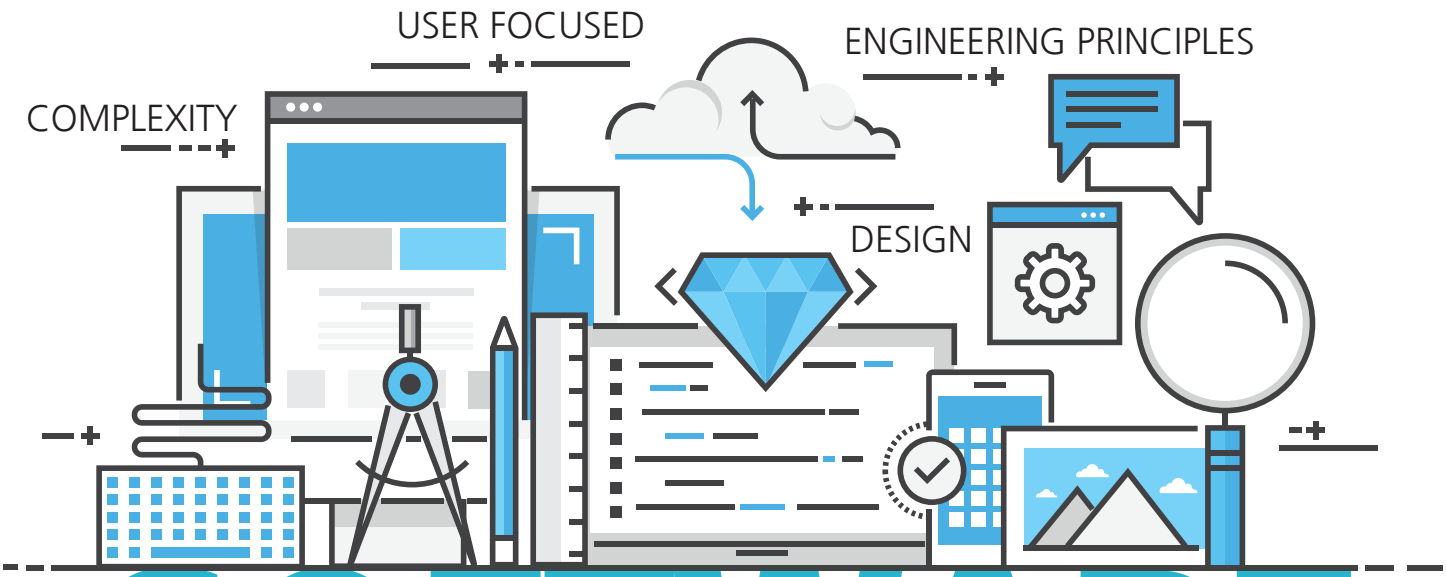
Algoma University, Bachelor of Arts in Information Technology

Concordia University College of Alberta, Bachelor of Science in Information Technology

Bishop's University, Bachelor of Arts in Information Technology

Mount Saint Vincent University, Bachelor of Applied Arts in Information Technology

Nova Scotia Community College, Information Technology Diploma

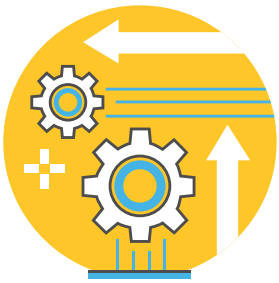


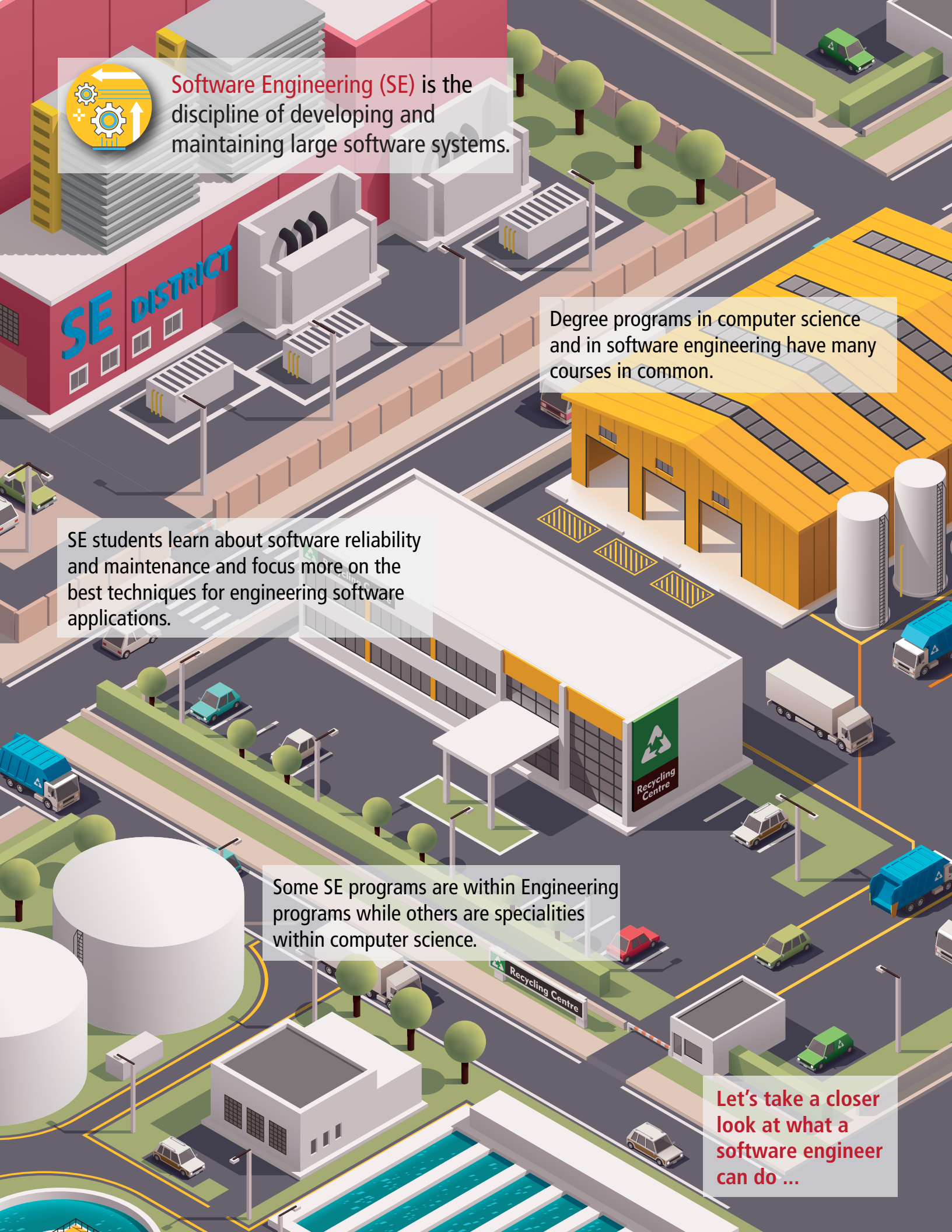
SOFTWARE ENGINEERING

Software Engineers develop and maintain large-scale software systems. Using the principles of mathematics and computer science, and the practices of engineering, software engineers learn how to develop software that meets customer needs.

Their focus is on software reliability, and they focus on techniques for developing and maintaining appropriate software solutions.

Software engineers work closely with customers, they learn how to assess customer needs and they often manage large, complex and/or safety-critical software projects.



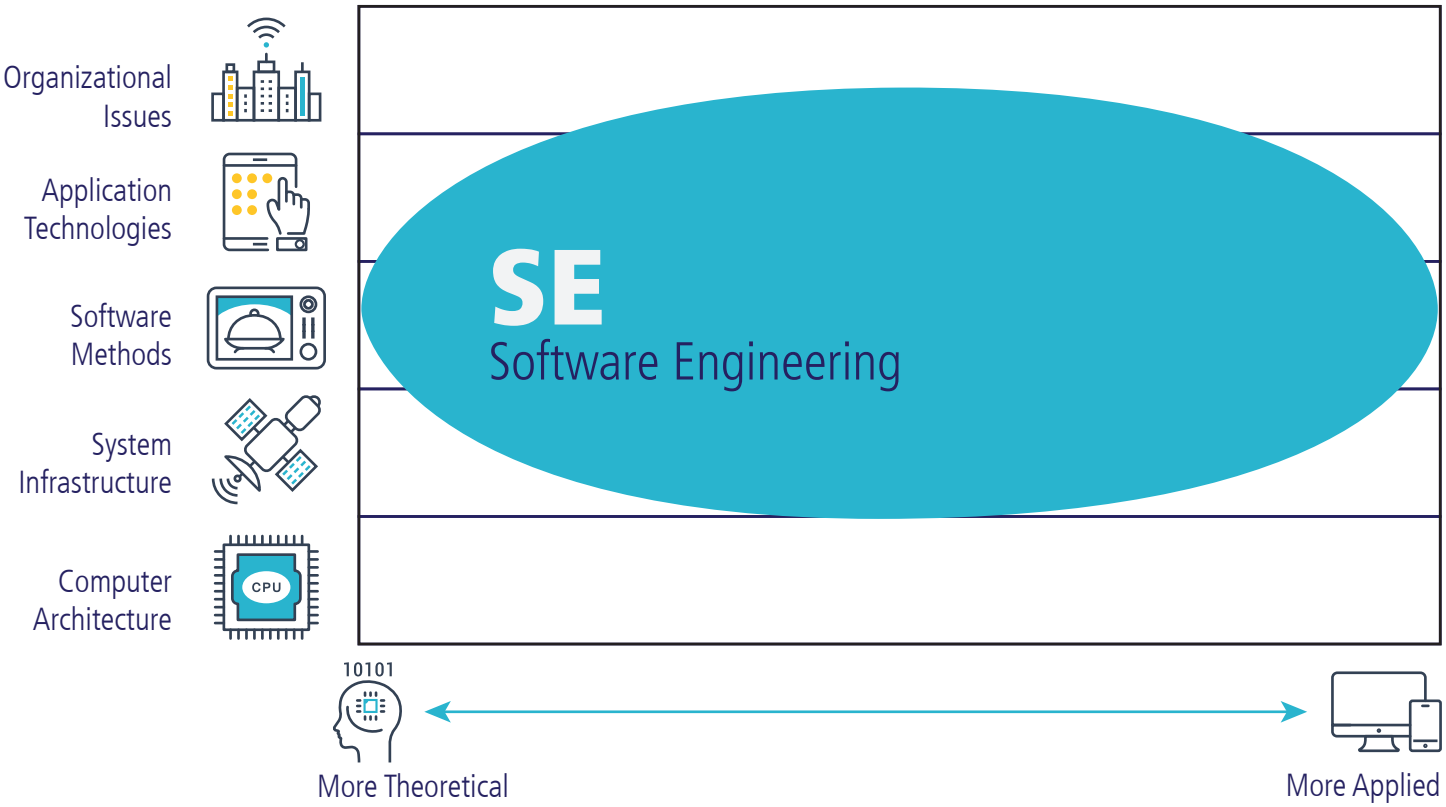

Software Engineering (SE) is the discipline of developing and maintaining large software systems.
SE DISTRICT
Degree programs in computer science and in software engineering have many courses in common.
SE students learn about software reliability and maintenance and focus more on the best techniques for engineering software applications.
Recycling Centre
Some SE programs are within Engineering programs while others are specialities within computer science.
Recycling Centre
Let's take a closer look at what a software engineer can do ...


Software Engineering
In Software Engineering (SE) we are focused on how to best develop large-scale, reliable software systems.
We use special design techniques so that software is more likely to be reliable and correct.
add to cart
We are interested in learning and improving software design principles.
We may supervise a team of developers.
We need to be able to assess user needs and develop usable software.
We also develop new testing techniques to create safer software.
We are often engineers, which means we also have traditional engineering skills and training.
We sometimes do many of these same tasks over in Computer Science as well.
Computer Engineering has some similarities, but we are more focused on the connection between software and hardware.
CS
CE

SOFTWARE ENGINEERING

Summary

Software Engineering is focused on everything (from applied to theoretical) related to software methods, that is, writing software. Infrastructure and application technologies are also part of software engineering.



On the Job

Focuses on large-scale systems development.

Designs testing procedures for large-scale systems.

Utilizes theory to research and design software solutions.

Develops software systems that are maintainable, reliable, efficient, and satisfy customer requirements.

Utilizes sound engineering practices to create computer applications.

Manages a team of software developers.

Core Courses

Mathematical and Engineering Fundamentals

Programming Fundamentals

Software Modeling and Analysis

Software Design and Processes

Software Quality Assurance

Software Security

Software Project Management

Data Structures and Algorithms

Sample Programs

University of Guelph, Bachelor of Computing in Software Engineering

University of Victoria, Bachelor of Engineering in Software Engineering

University of Calgary, Bachelor of Science in Software Engineering

University of Manitoba, Bachelor of Science in Software Engineering

Concordia University, Bachelor of Engineering in Software Engineering

University of New Brunswick, Bachelor of Science in Software Engineering

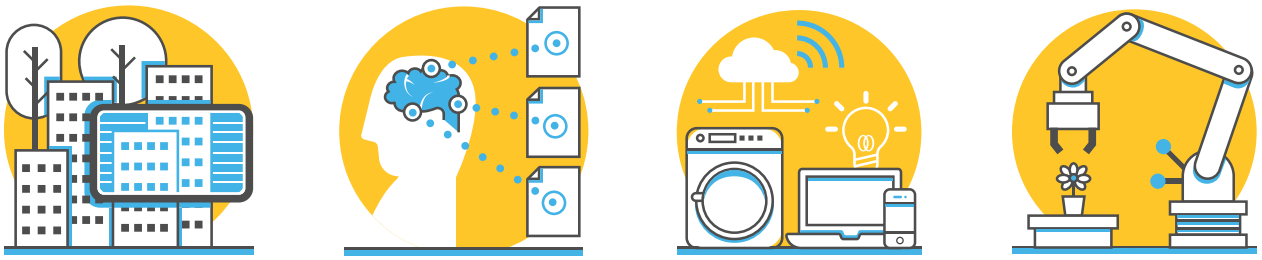
Sheridan College, Computer Systems Technician – Software Engineering

OTHER SPECIALIZATIONS

Not every computing program that you find in a college or university will have one of these five ACM discipline titles. For example, we now see undergraduate degrees in Game Design, Cyber-Security, and Computer Applications. Many universities also offer mixed majors that combine computing with a variety of other disciplines, including Computational Science, BioInformatics, Computational Arts, and Computing and Health Sciences.

One-year certificates, two-year diplomas, and three-year applied or associate degrees provide dozens of other options, either as stand-alone training or post-degree specialization. These programs often use a variety of titles which don't always map to the five ACM discipline areas.

To make it more confusing, the job title you have in a company might not sound like the program you took. For example, Network Administrators could have backgrounds in Computer Science, Information Systems, or Information Technology.

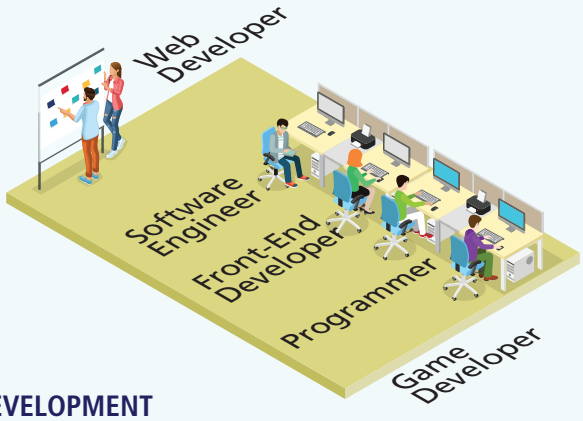


WHAT ASPECT OF COMPUTING WILL I FOCUS ON?

MOST COMPUTING JOBS FALL INTO ONE OF THE GENERAL CATEGORIES SHOWN IN THE BELOW DIAGRAM AND WHICH ARE EXPLAINED IN MORE DETAIL ON THE FOLLOWING PAGE. NOTICE THE PEOPLE ON THE STAIRS: THEY REPRESENT THE FACT THAT PEOPLE WORKING WITHIN DEVELOPMENT CAN OFTEN FIND THEMSELVES MOVING TO OTHER TYPES OF JOBS.

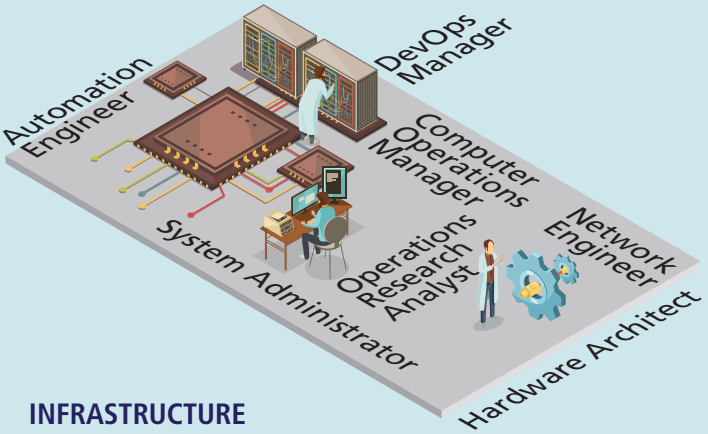
THERE ARE MANY, MANY, MANY DIFFERENT TYPES OF COMPUTING JOBS. IF THERE IS ONE THING WE HOPE THAT THIS GUIDE TEACHES YOU IS THAT COMPUTING IS MUCH MORE THAN JUST PROGRAMMING!

THIS PAGE ILLUSTRATES SOME EXAMPLE COMPUTING JOB TITLES, ORGANIZED BY THE CATEGORIES SHOWN ON THE PREVIOUS PAGE.



DEVELOPMENT

These are the jobs most often identified with computing. The focus here is on software development, often referred to simply as programming. As you can see, there are many different labels for developers, each with a different focus.



INFRASTRUCTURE

Contemporary computing is dependent upon a sophisticated systems infrastructure. The jobs in this area span a very wide range of tasks, from configuration and support, to designing and creating the devices themselves.

DATA

We live in a world that is over-flowing with digital data. Experts in this area help organize, analyze, and secure the data needs of organizations.

DESIGN

Most computing systems are used by humans, and as a result specialists are needed to make these systems attractive and usable as well as efficient and bug-free.

BUSINESS

Ultimately, computing systems are used by businesses and organizations. Specialists are needed to help optimize computing systems for business needs, as well as adopt business processes to new innovations.

MANAGEMENT

Like other business activities, computing requires managers. A manager might oversee a project, a development team, a computing department, or the information needs of an entire corporation.

RELATING JOB TITLES TO THE ACM COMPUTING DISCIPLINES

The following table provides examples of how some sample job titles relate to the five ACM disciplines, and shows where additional training may be needed.

As you can see, there is a lot of overlap. One of the amazing things about the computing industry is that over one's career, one can potentially have a variety of different jobs.

	Computing Discipline					
Job Title	**CE**	**CS**	**IS**	**IT**	**SE**	**Possible Additional Training**
Business System Analyst			★		★	Business/Commerce
Computational Scientist		★				Mathematics, Sciences
Computer Network Support Specialist	★			★		
Data Analyst		★	★			Statistics
Database Administrator		★	★	★		
Gaming & Multimedia Specialist		★			★	Graphic Design, Creative Writing
Hardware Engineer	★					Electrical/Electronic Engineering
Information Security Analyst		★	★	★		
IT/IS Consultant		★	★	★		
Medical Computing / Bioinformatics		★				Biology, Health Sciences, Statistics
Project Manager	★	★	★	★	★	
Quality Assurance Specialist	★	★	★	★	★	
Software Developer	★	★	★	★	★	
Systems Administrator	★			★		
Systems Analyst and Designer		★	★		★	
Web Developer / Designer		★	★	★	★	Graphic Design

RESOURCES

Links

For more occupational information, consider these free Canadian resources.

Canada – explore careers, wages, etc:
www.jobbank.gc.ca/explorecareers.do

Canadian Occupational Projection System:
occupations.esdc.gc.ca/sppc-cops

Simply Hired (Canada)
www.simplyhired.ca

Working in Canada:
www.workingincanada.gc.ca/home-eng.do

Alberta – Occupational Information:
www.alis.gov.ab.ca/occinfo

British Columbia: Work BC
www.workbc.ca/Jobs-Careers/Explore-Careers.aspx

Manitoba – Career Development:
www.manitobacareerdevelopment.ca

Nova Scotia – Explore Careers:
careers.novascotia.ca/searchjobprofiles

New Brunswick – Explore Careers:
www.nbjobs.ca/explore

Newfoundland and Labrador:
www.aesl.gov.nl.ca/lmi.html

Ontario – Job Profiles:
www.ontario.ca/page/labour-market

PEI – Career Development:
www.cdspei.ca

Yukon – Explore careers:
lmi.gov.yk.ca/en/explore-careers-and-industries

For additional information about computing education and careers, consider these additional sites.

Careers in Computing:
www.computerscienceonline.org

ACM Computing Curricula Recommendations:
www.acm.org/education/curricula-recommendations

ACM Career and Job Center:
jobs.acm.org

Career One Stop:
www.careeronestop.org

Association for Women in Computing:
www.awc-hq.org

Related Readings

For more information about disciplinary differences within computing, consider these readings.

ACM/IEEE (2005). *Computing Curricula 2005: The Overview Report*. This and the other discipline reports can be found at www.acm.org/education/curricula-recommendations.

ACM/IEEE (2010). *IS 2010 Curriculum Guidelines for Undergraduate Degree Programs in Information Systems*.

ACM/IEEE (2013). *Computer Science Curricular 2013: Curriculum Guidelines for Undergraduate Degree Programs*.

ACM/IEEE (2014). *Software Engineering Curricular 2017: Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering*.

ACM/IEEE (2016). *Computer Engineering Curricula 2016: Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering*.

ACM/IEEE (2017). *Information Technology Curricular 2017: Curriculum Guidelines for Undergraduate Degree Programs in Information Technology*.

Anthony E. (2003). Computing education in academia: toward differentiating the disciplines. In *Proceedings of the 4th Annual Conference on Information Technology Curriculum*.

Connolly, R., Miller, J., Uzoka, F. M., *et al* (2016). Red Fish Blue Fish: Reexamining Student Understanding of the Computing Disciplines. In *Proceedings of the 17th Annual Conference on Information Technology Education*.

Uzoka, F. M., Connolly, R., Schroeder, M., Khemka, N., & Miller, J. (2013). Computing is not a rock band: student understanding of the computing disciplines. In *Proceedings of the 14th Annual ACM SIGITE Conference on Information Technology Education*.

Uzoka, F.M., Miller, J., & Finch, D.J. (2017). *Computing You: Your Guide to a Career in the Computing Disciplines*. FDR Publishers: Calgary, AB. ISBN 978-0-9952277-0-5.

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