DIGITAL TRANSFORMATION

Handbook for digital transformation professionals

Editors:
Daina Gudoniene
Rita Butkiene

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Preface

Digital transformation helps businesses, governments, and institutions remain competitive by leveraging advanced technologies for efficiency, automation, and innovation. As industries increasingly adopt Artificial Intelligence (AI), the Internet of Things (IoT), and Big Data, employees and graduates must be equipped with digital skills to succeed in the modern job market. Universities and research institutions benefit from digital transformation through online learning, AI-driven analytics, and advanced research tools. Moreover, digital transformation enables greater access to education, services, and opportunities, particularly for underprivileged and remote populations.

Our developed courses “Robotics and IoT“, “Digital Education“, “Big Data“ and “Artificial Intelligence“ combine business, technology, and social sciences to provide a holistic view of digital transformation. By incorporating challenge-based learning into their courses, universities will integrate real-world projects, case studies, and internships to provide students with practical experience in emerging technologies.

Students should learn about Digital Education, AI, Big Data, Robotics, and IoT to understand how digital tools can optimize decision-making and operations. Programs emphasize responsible use of technology, cybersecurity, and ethical considerations in digital transformation.

Learning Digital Education helps students and teachers use modern tools like online platforms, virtual labs, and AI-driven learning to improve education quality and accessibility. AI courses teach students how machines learn, helping them develop skills for automation, problem-solving, and innovation in various industries. Big Data education enables learners to analyse large amounts of information, make data-driven decisions, and apply insights in business, healthcare, and research. Studying Robotics helps students understand automation, coding, and engineering, preparing them for careers in technology and manufacturing. IoT courses teach how smart devices communicate, helping students develop solutions for smart homes, cities, and industries.

These courses improve problem-solving, creativity, and critical thinking skills, making learners more adaptable to technological advancements. Students who learn these subjects gain a competitive advantage in the job market, as digital transformation is shaping all industries. By mastering these skills, learners contribute to future innovations and can create solutions that improve everyday life and business efficiency.

Editors

Professor Rita Butkiene, project coordinator

Associate professor Daina Gudoniene

Terms dictionary

According to Cambridge dictionary, https://dictionary.cambridge.org/

Curriculum	Relating to the subjects studied in a school, college, etc. and what each subject includes.
Digital Transformation (DT) Program	A set of courses about a digital transformation subject, especially in an educational course or by reading books.
Course	A set of classes or a plan of study on a particular subject, usually leading to an exam or qualification.
Topic	A subject that is discussed, written about, or studied in the course.
Massive open online course (MOOC)	A course of study that is made available over the internet and that can be followed by a large number of people.
Virtual assistant	A computer program or device that is connected to the internet and can understand spoken questions and instructions, designed to help you to make plans, find answers to questions, etc.
Chatbot	A computer program designed to have a conversation with a human being, especially over the internet.
Big data	A very large set of data that is produced by people using the internet, and that can only be stored, understood, and used with the help of special tools and methods.
Internet of things	Objects with computing devices in them that are able to connect to each other and exchange data using the internet.
Robotics	The science of making and using robots (= machines controlled by computers that are used to perform jobs automatically).
Distance education	A way of studying in which you do not attend a school, college, or

	university, but study from where you live, usually being taught and given work to do over the internet.
Artificial intelligence	The study of how to produce machines that have some of the qualities that the human mind has, such as the ability to understand language, recognize pictures, solve problems, and learn.
Challenge Based Learning (CBL)	Provides an efficient and effective framework for learning while solving real-world challenges.

INTRODUCTION

The aim of this document is to present the learning scripts for open online courses as part of the Digital Transformation curriculum, detailing course structure, materials, challenge-based activities and assessment. Each course was designed by a partner institution, and reviewed by the others:

- **Robotics and IoT**, author: Jochen Dickel, Fachhochschule des Mittelstands, Bielefeld, Germany
- **Digital Education**, author: Sirje Virkus, University of Tallinn, Estonia
- **Big Data**, authors: Rita Butkiene, Daina Gudoniene, Lina Ceponiene & Evaldas Vaiciukynas, Kaunas University of Technology, Lithuania
- **Artificial Intelligence**, authors: José Coelho & Vitor Rocio, Universidade Aberta, Portugal

Digital transformation (DT) has become a mandatory effort for all organizations, as the proliferation of technologies is driving a growing efficiency of business processes. However, such transformation can only be done with people, it is not enough to “throw technology” onto the processes: employees must be involved and be a part of the process. Training is needed at two levels: management level, where coordinators redefine and reengineer processes according to business needs and applicable technology; and at execution level, where employees must interact with technology in order to carry out the defined processes in the most efficient way.

The proposed digital transformation curriculum intends to familiarize learners with key subjects: big data, digital education, artificial intelligence, robotics and IoT. Each of these technologies is essential for DT, as they relate to emerging issues in contemporary organizations that drive change and have the potential to transform business models. We briefly describe the associated courses and contextualize them in DT scenarios:

1. Robotics and IoT

The course on IoT and Robotics covers a wide range of topics related to Internet of Things (IoT) and robotics. It provides an introduction to the definition of IoT and robotics, and the benefits and challenges associated with their integration. The course covers different IoT and robotics technologies, their applications in various fields. It also covers the design and development of IoT and robotics systems, including hardware, software, and network architectures, user interfaces and control systems. The course explores the ethical and legal issues related to privacy, security and job displacement. The course also provides insights into future trends in IoT and robotics, such as cobots, swarm robotics, edge computing, autonomous vehicles, and smart cities. The course aims to equip students with the basic knowledge and skills needed to design IoT and robotics systems for simple applications and an overview about its development and implementation.

The program is organized in four courses, corresponding to the subjects described above, with 1.5 ECTS each (~40 hours), and is delivered in a MOOC format: online and open to everyone. Learning resources are open, based on an OER (open educational resources) philosophy. The format of the courses and learning resources allows integration of the courses (or parts thereof) into existing programs in the partners' institutions.

Pedagogical approach is founded on challenge-based learning (CBL), and since student support must be kept to a minimum in MOOCs, automated mechanisms are introduced, in particular chatbots, in order to help learners in their learning path.

In this document we describe the methodology for designing and developing the curriculum and each individual course in the Digital transformation study programme, as well as provide a template for the DT program and course descriptions.

We are planning innovative solutions for developing and implementing DT curriculum to be described below: (i) MOOCs methodology main issues, (ii) challenge-based learning, (iii) virtual assistance.

2. Digital Education

This course on "Digital Education" covers various topics related to digital education, starting with an introduction to defining digital education and the benefits and challenges associated with it. It covers different learning theories that apply to digital education, online learning strategies, and pedagogical approaches for online teaching. The course also explores digital tools for education such as learning management systems, social media, collaborative tools, interactive multimedia, and artificial intelligence. Students will learn about instructional design principles for digital education, multimedia content creation, and adaptive learning design. The course also focuses on assessing and evaluating online learning programs through different types of assessments, rubrics, and open digital badges. It highlights policies and ethical issues in digital education such as copyright and intellectual property, privacy, security concerns, and accessibility and inclusivity. Finally, the course provides insights into future trends in digital education such as emerging technologies, predictive analytics, learning analytics, microlearning, and gamification.

Problem-based learning (PBL) could be used in this course. Open digital badges are used in a course to support personalized learning providing customized learning pathways for students based on their interests and learning goals. For example, students can earn badges for completing specific modules or units of study, and these badges can be used to unlock additional learning opportunities or resources that align with their interests. Open digital badges can be also used to motivate and engage students in the learning process by recognizing their achievements and progress. Badges can be designed to appeal to different learning paths, styles and preferences, and can be used to encourage students to take ownership of their learning and strive for excellence.

3. Big Data

The course on "Big Data" provides an overview of the fundamental concepts, tools, and techniques used in the processing, analysis, and visualization of large amounts of data. The course will begin by introducing the concept of big data and its importance in various domains. It covers the basic principles of data management and preprocessing, as well as the latest technologies and tools, including API and web scraping, ETL (extract-transform-load) steps, R programming, and dashboard design.

To provide students with practical experience in big data analytics, the course uses a challenge-based learning approach. Students will seek to develop solutions for real-world big data problems using the latest tools and technologies to solve the micro-challenge. The course also emphasizes the importance of data visualization and storytelling, helping students to communicate their findings effectively to a non-technical audience.

Overall, the course on "Big Data" empowers students with the skills and knowledge necessary to work with large-scale data and leverage it to drive business value and societal impact.

4. Artificial Intelligence

The growing digitization of society is a reality that we have been witnessing, with the adoption of products and technologies that have transformed our personal lives, revolutionizing our relationship with information and communication. At the organization level, digital transformation is also motivated by the dissemination of several innovative technologies, potentially transforming business. This course addresses the main aspects of Artificial Intelligence (AI) and modern Machine Learning (ML) techniques, with a perspective of the impact on modern organizations, contextualizing them in business and organizational scenarios of digital transformation.

The course will start by delimiting and defining the concepts of intelligence, AI and ML, followed by an overview of large areas within AI. Problem solving techniques are explored: decision, search, optimization. Knowledge representation, as a key aspect, is introduced, focusing on up-to-date methods. Besides the fundamental concepts of AI, studied since the 60s, recent developments in machine learning/deep learning and natural language processing are introduced, by showing and experimenting with computational systems that are becoming increasingly available.

To develop and consolidate practical skills, challenge-based learning is proposed to the students, with some micro and medium size challenges, founded on real problems, and, if possible, in the context of industry or research partnerships.

(i) MOOCs methodology main issues

According to the Cambridge dictionary “A massive open online course (MOOC) is a course of study that is made available over the internet and that can be followed by a large number of people”.

Massive open online courses (MOOCs) have been prominent since the early 2010s, assuming two main approaches: cMOOC, or connectivist MOOCs, and xMOOC (extended MOOCs). cMOOCs were proposed by Stephen Downes (Bates, A., 2015), focusing on connections among learners, being community based. On the other hand, xMOOCs relate to more traditional online course delivery, with a rigid structure and aimed at large numbers of students.

Several specific aspects related with the content to be designed according to the MOOC conception need to be defined.

MOOCs suggest very different pedagogical and technological models as well as various kinds of content: course material, readings, problem sets and place for communication such as interactive user forums for communication in a community of students, professors or teaching assistants, different tests and assignments (Rutkauskiene & Gudoniene, 2017). Variations and particular models of the MOOC concept have been proposed, promoting pedagogical approaches, such as iMOOC (Coelho et al., 2015), which addresses student-centered learning in a context of interaction in an open social context. MOOCs have been used mostly as stand-alone online courses without credits. However, some researchers, teachers, colleges, and universities have attempted to utilize MOOCs in blended format in traditional classroom settings. This paper reviews some recent experiments in the context of current trends in MOOCs by examining methodologies utilized in blended MOOCs in a face-to-face environment (Israel, 2015).

There are several general recommendations for MOOCs design. At the time when the course is designed, the platform should offer the possibility of uploading documents and video lectures (hosted in YouTube and afterwards linked to the platform) as the main learning resources, structuring the course (Figure 1). In addition, the platform should offer the possibility of adding multiple choice tests and peer-review assignments as assessment activities. There should also be built-in social tools supported by the platform and aimed at fostering students' participation and collaboration: a Questions & Answers (Q&A) tool, and a forum (Alario-Hoyos et al., 2014).

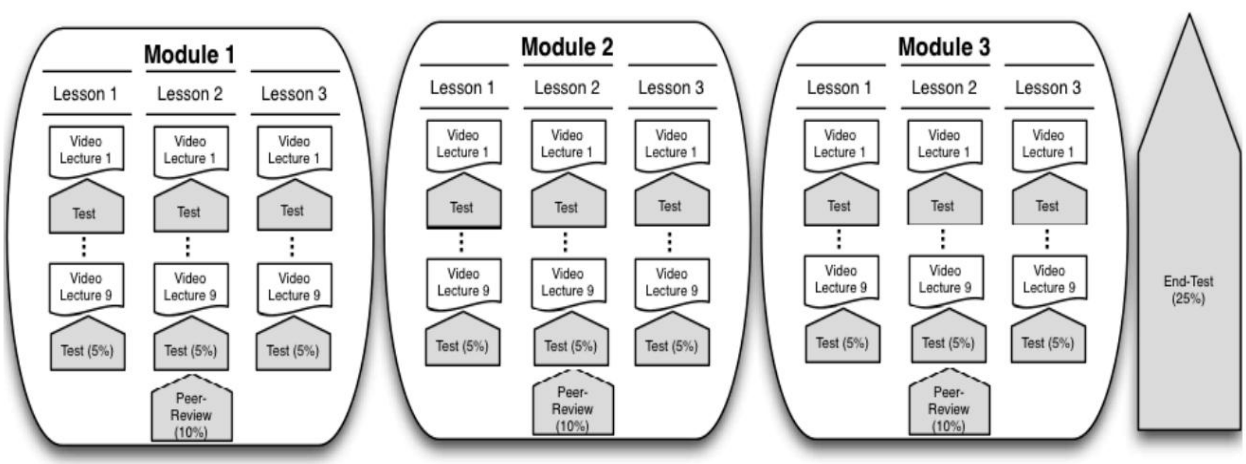

Figure 1. Structure of the course, including video lectures, formative tests
(not taken into account to calculate students' scores),
summative tests and peer-review activities (Alario-Hoyos et al., 2014).

There are several quality factors directly related to the quality of MOOCs. This definition reduces Open Education not only on the open access but also includes further legal dimensions such as open licensing and open availability as well as operational dimensions such as open resources, open technologies and open standards as well as visionary dimensions such as open methodologies, open recognition and open innovations (Stracke, 2017).

Quality of MOOCs is a subject of discussion, as phenomena such as high drop-out and non-completion rates are prominent.

(ii) Challenge based learning (CBL)

Challenge-Based Learning (CBL) provides an efficient and effective framework for learning while solving real-world challenges.

The application of CBL has increased in higher education institutions, fostering student transversal competencies, knowledge of sociotechnical problems, and collaboration with industry and community actors. However, a broad range of different frameworks, hybrid approaches, and educational interventions are using this term to define their approach (Gallagher and Savage, 2020). Moreover, a challenge-based learning experience is a learning experience where the learning takes place through the identification, analysis and design of a solution to a sociotechnical problem. The learning experience is typically multidisciplinary, takes place in an international context and aims to find a collaboratively developed solution, which is environmentally, socially and economically sustainable (Gallagher and Savage, 2020).

Industry and community collaboration are also identified by institutions in strategic goals and research funding applications. Improving the link between academia and industry is crucial for the advancement of knowledge, innovation in design and development, and providing solutions to transdisciplinary societal problems (Trinity College Dublin, 2020).

Both formative and summative assessment are used within CBL approaches, including workshop attendance and participation, oral presentations, hackathons, peer evaluations, conference paper reports, laboratory reports, open book exams, quizzes and progress reports can be used for assessment process implementation and assessment rubrics to be used to assess student performance.

Given the wide variability of CBL approaches, a conceptual framework (Figure 2) could be used to support CBL implementation and ensure that if CBL is being used, each of these characteristics are embedded, in some way, within the design. Ultimately, this framework may help standardization of the CBL term, currently lacking within teaching and academia and could be augmented in the future as CBL evolves.

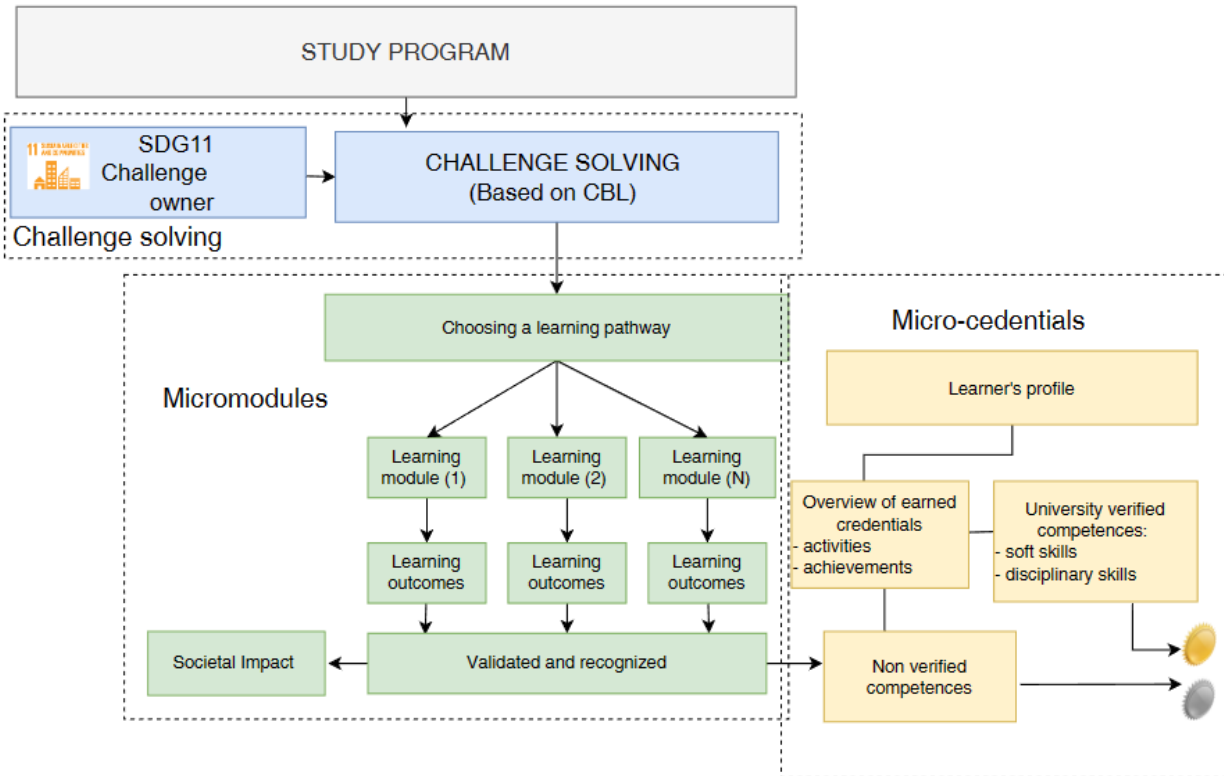

Figure 2. CBL in engineering education (Gudoniene et al., 2021).

Global themes, real-world challenges, collaboration, technology, flexibility, multidisciplinary and discipline specificity, challenge definition, and creativity and innovation are the most common emerging themes from exploring CBL research definitions. Although there is variance between CBL practical approaches, these key themes were present in most research reviewed. However, what is notable is the lack of practical implementation of some themes described by the studies, such as multidisciplinary teaching. For example, the majority of CBL projects within higher level institutions were delivered to STEM students, even though CBL at its core is a multidisciplinary pedagogy. Using challenge-based teaching in non-STEM higher level courses appears to be a significant gap in the research and future should consider exploring multiple disciplines in the design, analysis and evaluation of CBL (Gallagher and Savage, 2020).

(iii) Virtual assistance

Virtual assistance plays a significant role in online education, providing support and guidance to students who are studying remotely. However, there are several challenges associated with virtual assistance in the online course context, including:

- *Technical difficulties:* Technical issues, such as slow response times, connectivity problems, and software malfunctions, can disrupt the virtual assistance experience and hinder student learning.
- *Lack of personal interaction:* In virtual assistance, the lack of personal interaction can make it difficult for students to build relationships with their instructors or receive the support they need. This can also make it harder for instructors to understand students' individual needs and challenges.
- *Quality control:* Ensuring the quality of virtual assistance can be difficult in an online course context, as there is often less direct supervision and less opportunity for real-time feedback.
- *Limited scope of services:* Virtual assistance in an online course may have limitations in terms of the type of support it can provide, such as not being able to provide hands-on demonstrations or in-person consultations.
- *Limited access to resources:* In some online courses, students may have limited access to resources, such as library materials or technology, which can impact their ability to receive virtual assistance effectively.
- *Language barriers:* For students who speak a different language or are not fluent in the language of the virtual assistance service, language barriers can be a significant challenge.
- *Security and privacy concerns:* With virtual assistance in an online course, sensitive student information, such as personal and financial details, is often exchanged over the internet, which raises concerns about data privacy and security.

The use of chatbots to provide virtual assistance is a solution for providing virtual assistance in an automatic way, for instance to: support learning, assist students in administrative and campus issues, and mentoring (Wollny et al., 2021). In the Digital Transformation curriculum, several types of chatbots will be proposed, associated with the courses.

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1. ROBOTICS AND IOT

Relevance: Robotics and Internet of Things (IoT) are changing more and more all areas of life. Automation and real-time data exchange enable smart solutions in healthcare, manufacturing, logistics and many other areas by increasing efficiency, precision and interconnectivity. However, these technologies also pose significant risks, such as privacy invasion, security threats, and potential job loss. To harness the transformative potential of Robotics and IoT, it is therefore crucial to understand their risks and to practice a responsible and ethical approach.

Objective: the course aims to provide a comprehensive understanding of IoT and Robotics, their different fields of applications, ethical implications, technical foundation and basic skills to design and model IoT and Robotics solutions.

Learning outcome: By the end of the course, students will have acquired sufficient knowledge of Robotics and the Internet of Things, enabling them to use these key technologies of the 21st century to solve challenging problems. In particular, students will be able to:

- Define the IoT and Robotics, including their main concepts and questions.
- Identify the various application fields of the IoT and Robotics.
- Understand the underlying principles of IoT and Robotics technologies.
- Analyze and reflect on ethical issues related to IoT and Robotics.
- Conceptualize, design, and model a user-centered IoT/robotic solution based on a case study.
- Optional: Build and test a prototype for IoT and robotics solutions.

TOPIC 1.1. Introduction to Robotics and Internet of Things

Figure 1.1.1. Asimo, robokind ambassador (HONDA).

Learning Objectives

After completing this topic, you will be able to define the main characteristics of robotics and the Internet of Things (IoT), give an overview of the application areas of these technologies, reflect on their benefits and challenges and know the historical background.

Topic content

Student activities before starting

Create an experience report about IoT and Robotics in your personal environment: Investigate the importance of Internet of Things and Robotics in your environment. For example, observe where these technologies are used in studies, at work, at home, in public spaces etc. Examine what purpose it is used for and what benefits are generated. Which of these areas of application did affect you directly? What advantages and disadvantages do you see personally and in general?

VIDEO 1.1. Introduction to Robotics and Internet of Things [*duration 7:00 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/64424/course/section/2413/Topic%201%20Introduction%20to%20the%20Internet%20of%20Things%20%28IoT%29%20and%20Robotics.mov

Lesson 1.1.1. Robotics: Definition, Benefits and Challenges

What is a robot?

Robots are mechanical or virtual systems capable of performing tasks autonomously or semi-autonomously. This is a very broad definition. In fact, Robots are very diverse. They ride on wheels, walk on two, four or even six legs. Some can swim, dive or take to the skies. Some robots assemble sensitive microchips in high-tech facilities. Others work in dusty car factories. Still others help diagnose and treat diseases. Robots range in size from a thumbnail to a refrigerator. Some robots can make pancakes. Others can land on Mars.

This diversity in size, design and capabilities makes it difficult to come up with a definition for the term "robot." The images 1.1.1 – 1.1.6 show just a few examples from the wide range of areas in which robots can be used.

Figure 1.1.2. SmartBird flies like a bird (FESTO).

Figure 1.1.3. Aibo wants to play: a consumer Robot with entertainment Functions (SONY).

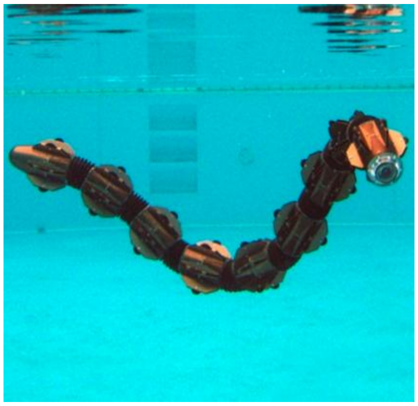

Figure 1.1.4. ACM-R5H snakebot goes swimming

Figure 1.1.5. YuMi, human-machine collaboration robot (AB)

(TOKYO INSTITUTE OF TECHNOLOGY).

Figure 1.1.6. Da Vinci Diagnostic: This robot assists doctors with complex examinations and surgical procedures (INTUITIVE SURGICAL).

Where does the name "robot" come from?

The term robot is derived from the Czech/Slavic word “robota”, which means work or drudgery. The Czech writer Karel Čapek first referred to machine people as robots in the play “R.U.R. - Rossum's Universal Robots”, published in 1920. The term "robot" means different things to different people. And even roboticists themselves have different ideas about what a robot is and what it is not. We mostly know what a robot should look like and what it should be able to do from science fiction movies.

Robotics as a Discipline

Robotics is an interdisciplinary field that deals with the development, design, and application of robots. Robotics combines various fields such as mechanics, electronics, computer science, and artificial intelligence to develop systems capable of performing human-like tasks. This can range from simple tasks such as grasping objects to complex tasks such as autonomous navigation in unknown terrain.

Two Definitions of a robot

So, what makes a robot? Here are two definition that's neither too general nor too specific:

Definition 1 (Robot Institute of America, 1979):

> *"A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks".*

Definition 2 (Guizzo, 2023):

> *"A robot is an autonomous machine capable of sensing its environment, carrying out computations to make decisions, and performing actions in the real world".*

Roboter versus Automate

An **automate** is a machine that can perform a specific task automatically, but only this task. For example, a coffee machine can brew coffee, but nothing else. And a CNC milling machine can be programmed, but in the end it can only mill. If this operation is no longer needed, an automatic machine is useless. A **robot**, on the other hand, can be programmed and retooled and can thus be used for many tasks. The special feature of a robot is its **flexibility**. Where a vending machine can only repeat the predefined operation, a robot can be reprogrammed to grip or assemble.

Benefits of robotics

The benefits of robotics are diverse, just as the fields of their application. They range from industrial automation, where robots are used in factories to perform repetitive tasks, to medicine, where robots are used in surgery to perform precise procedures. Applications of robotics can also be found in aerospace, logistics, and the home. Additionally, they're used in education for teaching and research to name just a few.

The following overview shows the most important application areas that benefit from robotics:

- Industrial robotics: industrial robots are used in factories to automate repetitive tasks such as assembly, welding, painting, and packaging.

- Medical robotics: in medical robotics, robots are used in surgery to perform precise and minimally invasive procedures. They can also help with patient rehabilitation and care.
- Agricultural robotics: in agriculture, robots are used to automate tasks such as planting, harvesting, and weeding. They can also help monitor crops and animals.
- Logistics robotics: in logistics, robots are used to transport, sort and store goods. They can also help with picking and packing products.
- Service robotics: service robots are used in a variety of settings, including hotels, restaurants and hospitals, to perform tasks such as cleaning, delivering food and drinks, and receiving and entertaining guests.
- Military and security robotics: robots are used in military applications to perform tasks such as reconnaissance, defusing bombs and rescuing people in dangerous situations. They can also help monitor borders and public places.
- Educational and research robotics: robots are used in schools and universities to teach students about programming and robotics. They are also used in research to develop new technologies and applications.

Challenges of robotics

Robotics impacts all areas of life raising a variety of social, technical and ethical issues.

For example, there is the question of the impact of robots on the labor market and what responsibility this implies for decisions in economics. There are also discussions about privacy and security in the context of autonomous robots. The following overview shows the multitude of risks that are often associated with each other:

Socio-economic Risks

- Job Displacement: Risk of unemployment due to automation.
- Inequality: Uneven distribution of access to and benefits from robotics.

Technical and Security Risks

- Privacy and Security: Potential for hacking leading to privacy breaches or malicious use.
- Safety: Risk of accidents due to malfunctions or programming errors.

- Dependence on technology: Over-reliance leading to diminished human skills and vulnerability if systems fail.

Ethical and Environmental Risks

- Ethics and Dehumanization: Risk of emotional detachment and dehumanization of personal relationships.
- Environmental Impact: Pollution and resource depletion from production and disposal of robots.

Lesson 1.1.2. Internet of Things Definition, Benefits and Challenges

What is the Internet of Things (IoT)?

The Internet of Things (IoT) describes the network of physical objects ("things"), that are embedded with sensors, software, and other technologies for connecting and exchanging data with other devices and systems over the internet. For this purpose, sensors and actuators embedded in physical objects are linked through wired and wireless networks as the diagram below (Figure 1.1.7) shows:

Figure 1.1.7. Internet of Things (Kemal, 2019)

Benefits of the Internet of Things

The IoT enables greater automation and control in many areas, from home automation to health monitoring to industrial automation. Here's an overview of different application areas:

- Connected Cars: IoT in cars allows for real-time data collection and sharing, improving navigation, maintenance, safety, and enhancing driver experience.
- Smart Appliances: IoT-enabled appliances automate tasks, manage energy use, provide convenience through remote control and enhance household efficiency.

- Connected Security Systems: IoT integrates cameras, sensors, alarms, providing real-time monitoring, instant alerts, and enhancing safety and security at home or work.
- Smart Agriculture Equipment: IoT devices monitor soil, weather, crop health, automate irrigation and fertilization, boosting productivity and sustainability in agriculture.
- Connected Retail: IoT in retail enhances customer experience with personalized recommendations, inventory management, and streamlined checkouts, driving business growth.
- Connected Healthcare Monitors: IoT in healthcare enables real-time patient monitoring, preventive care, personalized treatment, improving patient outcomes significantly.
- Connected Manufacturing Equipment: IoT enhances manufacturing efficiency with real-time monitoring of machines, predictive maintenance, reducing downtime and optimizing production.
- Connected Cities: IoT transforms cities into smart cities, optimizing utilities, improving transportation, enhancing public safety, and promoting sustainable living.

Challenges of Internet of things (IoT)

The Internet of Things (IoT) offers many benefits, but there are also some challenges. Not everyone has the same access to IoT technologies. This can lead to a widening of the digital divide between those who have access and those who do not. In addition, the automation of jobs through IoT could cause some people to lose their jobs.

There are also security-related challenges. IoT devices collect a lot of data, and that can cause privacy issues. These devices can also be vulnerable to hacking, which poses risks to data security and our physical security. Many IoT devices also don't have very strong security standards, which makes them even more vulnerable.

There are also ethical challenges. It is often not clear what data IoT devices collect and how it is used. This can cause issues with transparency and consent. And if we become too dependent on IoT devices, it could limit our human autonomy.

To address these challenges, we need clear rules and guidelines, both at the technological and policy levels.

Lesson 1.1.3. Historical Background and evolution of Robotics and Internet of Things

Evolution of the Internet of Things

Let's talk about the evolution of the Internet of Things (IoT). An older term that goes with it is "machine-to-machine" or M2M for short. This refers to devices talking directly to each other and doing things without humans having to help. This can happen over wires or wirelessly.

A well-known example of this is telemetry. It has been used to transmit data since the beginning of the last century. The first to do it used telephone lines and later radio waves to send measurement data. M2M communication is an important part of the IoT and is often used for remote monitoring, control and automation.

The idea of networked devices has been around since the 1970s. Back then, people often talked about "embedded Internet" or "ubiquitous computing." But the term IoT wasn't invented until 1999 by Kevin Ashton, when he was working at Procter & Gamble and promoting RFID technology. The term IoT then became really well known in early 2014.

The difference between M2M and IoT lies primarily in the type of network. With M2M, the devices communicate directly with each other via various connections. With IoT, they exchange their data via a data cloud. This enables even more complex networked solutions than M2M.

Activity

Read the article “machine-to-machine M2M” at https://www.techtarget.com/iotagenda/definition/machine-to-machine-M2M (TechTarget). This page provides a comprehensive definition of M2M, with information on the applications and technologies that enable this type of communication.

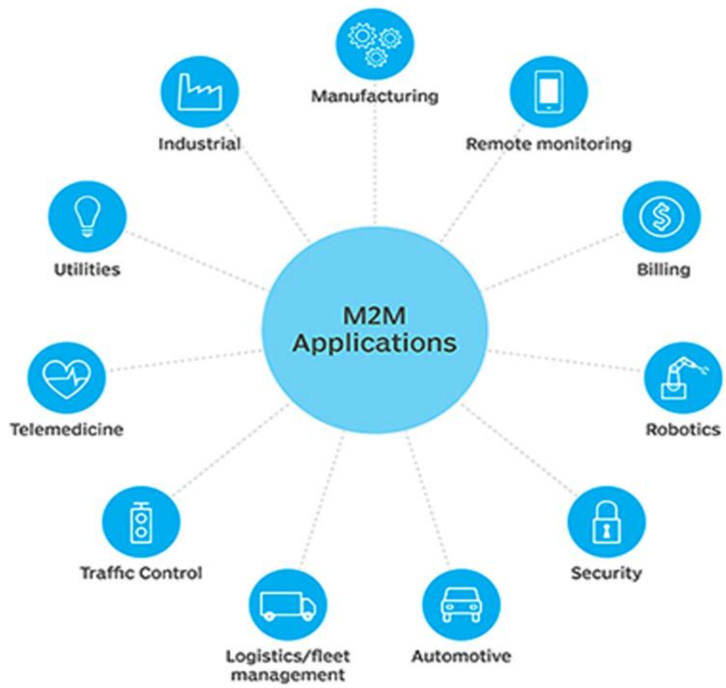

Figure 1.1.8. M2M applications (TechTarget).

Evolution of Robotics

Robotics has a long history, ranging from simple automated machines to complex, intelligent robots.

The first beginnings of robotics can be traced back to ancient Greece. People in the ancient Greece already built machines that performed simple tasks. But modern robotics began in the 20th century.

In 1961, Unimate, the first industrial robot, was installed on a General Motors assembly line to handle die-casting and welding (Figure 1.1.9). The Unimate robot, invented by George Devol and Joseph Engelberger, played a significant role in the development of industrial automation.

Figure 1.1.9. Unimate, the first industrial robot (IEEE Spectrum).

Learn more about Unimate at https://spectrum.ieee.org/unimation-robot.

The Stanford Arm

The 1970s and 1980s were a time of great progress. During this time, the first robotic arms were developed and used in manufacturing and laboratories. An important name from this time is Victor Scheinman, who invented the "Stanford Arm," one of the first versatile robotic arms (Figure 1.1.10).

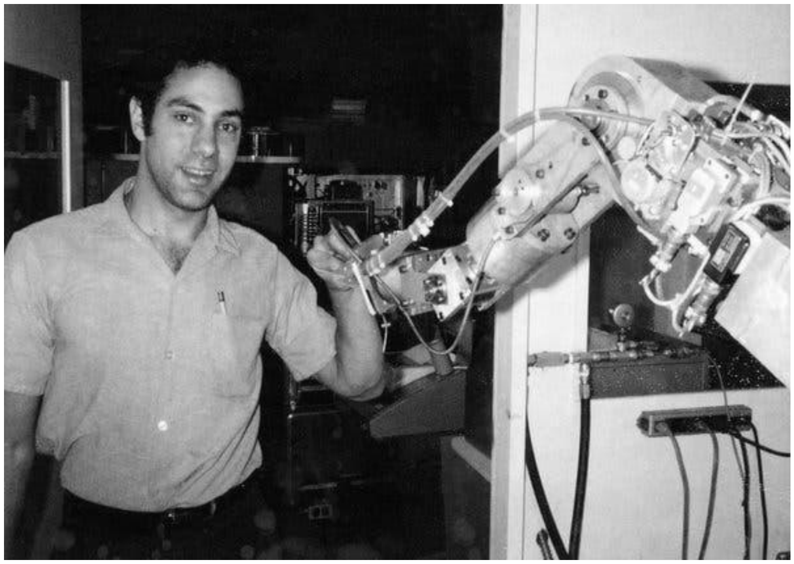

Figure 1.1.10. the Stanford Arm, a programmable six-jointed robot

(Bruce Baumgart/Stanford University Archives, Stanford School of Engineering).

Learn more about the Stanford Arm at https://www.nytimes.com/2016/09/22/technology/victor-scheinman-dead.html.

NASA Mars Rover "Sojourner"

In the 1990s and beyond, robotics evolved greatly. Robots became more intelligent and were able to perform more complex tasks. One example is the Mars Rover "Sojourner" which NASA sent to Mars in 1997 (Figure 1.1.11).

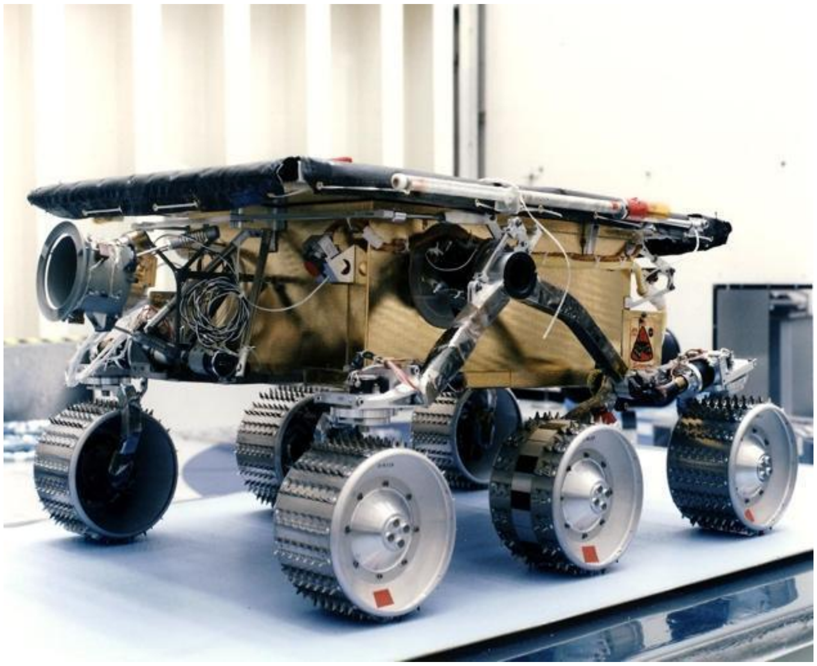

Figure 1.1.11. Mars Pathfinder Rover Sojourner (NASA, 1996).

Humanoid robots

In the 21st century, we see even more progress. Today there are robots working in homes, in hospitals, in factories and even in our space. One well-known robot is Honda's "ASIMO" humanoid robot, which can walk, run and even climb stairs (Figure 1.1.12 – 1.1.13).

Figure 1.1.12. ASIMO shows the sole of the left foot which is part of the Floor Reaction Control (Wikipedia).

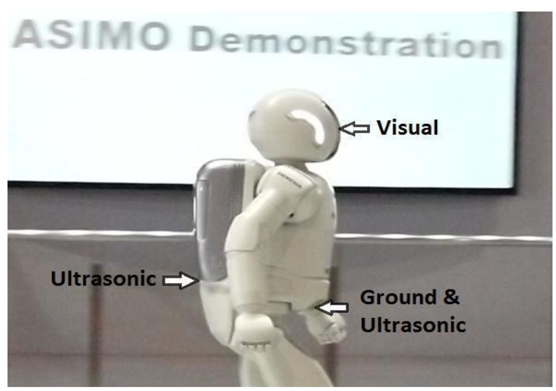

Figure 1.1.13. ASIMO environment identifying sensors which include visual, ground, and ultrasonic sensors (Wikipedia).

Consumer Robots

Rodney Brooks, a well-known robotics expert, has done much to make robotics what it is today for consumers. He co-founded iRobot, a company that makes the Roomba, the popular robot vacuum cleaner (Figure 1.1.14). Overall, robotics has evolved tremendously throughout history. And there's still plenty of room for progress and innovation.

Figure 1.1.14. Roomba Combo™ j7+ Robot Vacuum and Mop (iRobot).

Final note

As you have seen, the Internet of Things and robotics are fascinating technologies that can impact our lives in many ways. As with all technologies, they bring both benefits and challenges. It is up to us how we use them and what direction we give them. In the following chapters, we will take a closer look at the application issues and how robots and the Internet of Things work. So, stay curious and open to new things, and also cultivate your critical thinking!

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TOPIC 1.2. Application of Internet of Things (IoT) and Robotics

Learning Objectives

Upon completing this topic, you will be able to describe application areas and development trends in terms of case studies, technical and market feasibility as well as ethical and social implications of robotics and Internet of Things (IoT).

Topic content

Suggested activities for learners before starting this topic

Create a case study about IoT or Robotic based on one of your results from the last activity in Topic 1.1 (experience report). Investigate which stakeholders are involved, what are their contributions and what benefit they get from it. Assess the advantages and disadvantages of the project. Post your case study in in the forum and discuss your findings with other students.

VIDEO 1.2. Application of Internet of Things and Robotics [*duration 5:12 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/64424/course/section/2414/Topic%202%20Applications%20of%20the%20Internet%20of%20Things%20and%20Robotics.mp4

Lesson 1.2.1. Application areas of Internet of Things and Robotics

Robotics is used in many different fields of application. As the technology evolves, more and more new applications are discovered. And they still will get more in the future.

Figure 1.2.1. An employee at the Flex factory in Tcew, Poland (Flex).

Strengths and weaknesses of humans and robots

Before we look at some application fields, first let's explore the question of what special skills robots have compared to humans, what they are particularly good at and what they are not so good at. The Table 1.2.1 below shows a comparison of the strengths and weaknesses of humans and robots:

	Human 	**Robot / IOT** 
Strengths	Ability to react and interpret Ability to improvise Ability to learn Recourse to experience High flexibility	High positioning and repetition accurac High movement speed High strength and endurance Great coverage

	Ability to customization Sensory ability Association ability	High computing power High availability Ability to multitask
Weaknesses	Fatigue behavior Limited strength and endurance No real multitasking Limited availability Affected by short-term memory	No recourse to experience No ability to interpret No ability to improvise Relatively inflexible

Table 1.2.1. Comparison of the strengths and weaknesses of humans and robots (Petzold et al., 2021).

As you will have noticed, skills such as precision, endurance, strength and multitasking are where robots perform better than humans. On the other hand, humans are (at least still) superior to robots in terms of mental mobility and the ability to improvise and be creative. This in mind, now have a look at some examples from seven different fields of application.

IoT in Manufacturing

Figure 1.2.2. Human workers maintain machines in a factory.
Maintenance tasks can be taken over by IoT systems (Pixabay, by shixugang).

More and more manufacturing companies use IoT devices to monitor production flow, manage equipment, and alert about maintenance tasks (Figure 1.2.2). In those companies, the manufacturing environment is automated so that multiple machines can communicate with each other and be managed and diagnosed remotely. Suppose a machine gets hotter than it should. Then, IoT sensors automatically report this problem back to the system to alert technicians to the problems, minimizing downtime and ensuring smooth operations.

IoT in Logistics

Figure 1.2.3. Autonomous forklift works in a high-bay warehouse (Pixabay, by delphinmedia).

Logistics, in particular, has the potential to be at the forefront of this paradigm shift in manufacturing, but if we let it, it is likely to further complicate the relationship between logistics and the supplier network.

Andreas Tschiesner, Director of global management consulting firm Mckinsey & Company, said in a recent interview that leaner manufacturing along with robust algorithms can reduce inventory levels and delay times in parts delivery (Loeffel and Tschiesner, 2013). Siegfried Dais, deputy chairman of the board of Robert Bosch GmbH, added in the same interview: "Those who make the system user-friendly so that the people who use it every day can immediately identify problems and know how to do it without getting involved to become entangled in a web of dependencies" (Loeffel and Tschiesner, 2013).

The manufacturing IoT Infiltration

You could almost look at the Internet of Things in manufacturing as a pyramid of functions, as illustrated in the Figure 1.2.4.

At each stage, the autonomy of the IoT system increases and human dependency decreases. This allows the manufacturer to increase the efficiency of its production by saving material and storage costs, minimizing downtime and being able to react flexibly to changing market requirements.

As connected devices become cheaper, smaller and more powerful, new growth opportunities will emerge for any company that implements IoT into their production.

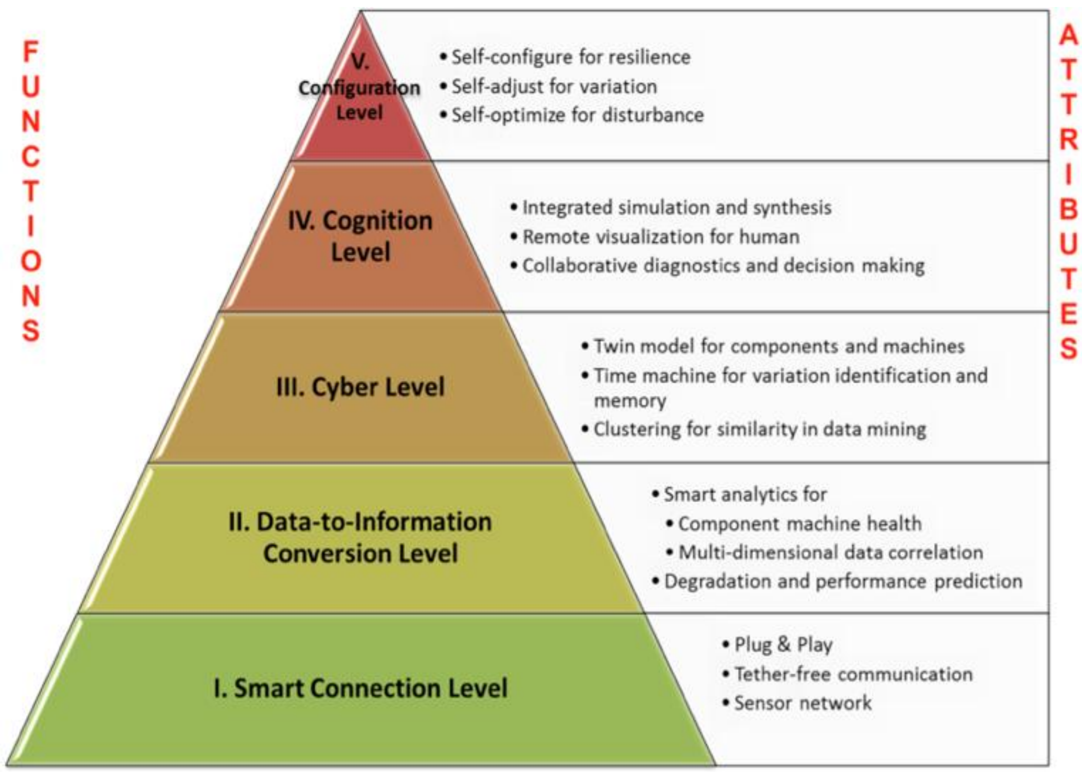

Figure 1.2.4. 5C Architecture for Designing Cyber-Physical Systems in Manufacturing (Behrad3d, Wikipedia).

Robotics in Manufacturing

Industrial robots are used in factories to automate repetitive tasks such as assembly, welding, painting, and packaging. Robots can do jobs like putting things together, which saves time and reduces mistakes.

Example: A robot in a car factory fits car doors to the car body. The robot gets a door from a conveyor belt and uses its mechanical arm to lift the door. It then precisely aligns the door with the car body and bolts it into place. All of this happens very quickly and with great precision. This robot can work non-stop without getting tired, and it does its job perfectly every time. So, it's faster and makes fewer mistakes than if a human was doing the same job.

Human-robot collaboration (HRC)

Figure 1.2.5. An employee at the Flex factory in Tcew, Poland (Flex).

Human-robot collaboration (HRC) involves direct interaction between humans and robots in the workplace (Figure 1.2.5). It merges human skills like problem-solving with robots' precision and endurance, emphasizing safety and ergonomics. This ensures a risk-free and productive partnership, allowing businesses to swiftly respond to market changes while considering employee needs.

Robots in HRC systems assist rather than replace human workers. They are equipped with sensors to respond to human presence and adapt through Artificial Intelligence (AI) and machine learning, enhancing their collaborative capabilities over time.

Agriculture

In agriculture, robots are used to automate tasks such as planting, harvesting, and weeding. They can also help monitor crops and animals. On farms, devices can check things like weather or soil quality. Robots can do jobs like planting seeds or picking fruits. Together IoT and robotic systems make farming more efficient, cost-effective, and precise, which benefits both farmers and consumers.

Example 1: As the robot picks the apple

Let's look at an apple-picking robot. This machine moves through the orchard using sensors and cameras to identify ripe apples based on their color and size. Once it finds a ripe apple, it uses a specially designed arm to reach the apple. The arm is gentle enough not to damage the apple or the tree but firm enough to securely grasp the apple.

The robot then carefully detaches the apple from the tree and places it in a collection bin. This process continues until all ripe apples are picked. Using a robot for this task can reduce the labor costs and speed up the harvesting process. Plus, the robot can work in all sorts of weather conditions and even at night, so the apples are picked as soon as they're ready.

The automation manufacturer KUKA is developing this robot for automated apple harvesting (Figure 1.2.6). Learn more about this exciting project at https://www.kuka.com/en-de/company/iimagazine/2022/automated-apple-harvesting.

Figure 1.2.6. Pilot project - The KUKA CropBot has mastered its first harvesting operation. It gently sucks the apples from the tree – supported by a vision system (KUKA).

Example 2: IoT in Agriculture – checking soil moisture in the ground

How does this IoT device check soil moisture? This is a sensor that's placed in the ground among the crops. It regularly checks how much water is in the soil by measuring the soil's ability to conduct electricity, which increases as the soil gets wetter. These sensors can check multiple spots, giving an accurate picture of the whole field's moisture levels.

Once the sensor detects that the soil is too dry, it sends a signal to a central system. This system could then automatically turn on the irrigation system, ensuring the crops get the right amount of water exactly when they need it (Figure 1.2.7). This setup not only saves water, but also can improve crop yields as plants get optimal growing conditions.

Read the case study here: https://www.mdpi.com/2073-4441/11/10/2061 (Millán et al., 2019).

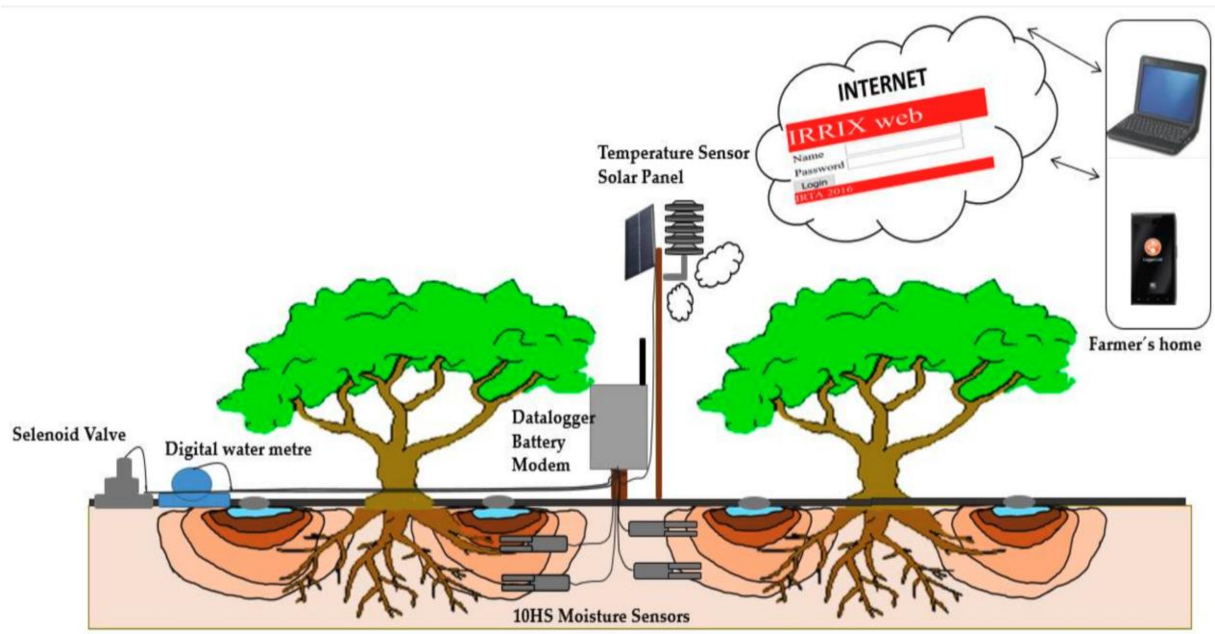

Figure 1.2.7. Components of an automatic irrigation system consisted of two fundamental components: (a) field equipment; and (b) the IRRIX software (Millán et al).

Education

In schools and universities, IoT devices can help create interactive and personalized learning experiences. Robots can help in teaching coding and other STEM (Science, Technology, Engineering, Mathematics) subjects, making learning more engaging and practical.

Example 1. A smartboard in a classroom that allows students to interact with lessons

Imagine you are in a classroom equipped with a smartboard (Figure 1.2.8). The teacher starts the lesson by presenting a math problem on the smartboard. Instead of just listening, you get to interact directly with the lesson. You walk up to the board and use your finger or a special pen to draw your solution right on the smartboard, which everyone can see. You can also move elements around on the smartboard, like numbers or shapes. This makes learning more engaging and fun. The smartboard can also be connected to the internet, so the teacher can pull up relevant videos or websites to supplement the lesson. This interactive and connected approach to teaching and learning is one of the ways IoT is transforming education.

Figure 1.2.8. Scenario of a hybrid classroom connection to IoT (Logitech, 2023).

Example 2. A robot that students can code to perform different tasks

Imagine you're in a programming class and your teacher introduces you to a small robot (Figure 1.2.9). This isn't just any robot – it's one you'll learn to control. The teacher explains that by writing code, you can make the robot do different things.

For your first task, you're asked to code the robot to move in a square. You use a simple programming language on a computer to write instructions for the robot. You tell it to move forward, turn right, move forward again, and so on. You upload your code to the robot and set it on the floor. With a press of a button, the robot springs to life, moving exactly in the square pattern as you programmed.

This hands-on approach makes the coding lesson exciting and real. You can see the results of your code in the actions of the robot, helping you understand the impact and power of programming. This practical use of robots is just one way robotics is enhancing education.

Figure 1.2.9. Students of secondary school learn to assemble and program a robot.
(Makeblock, 2023; retrieved from https://www.makeblock.com/blogs/for-educators/coding-robots-for-kids-elementary-school-middle-school-high-school on 21.07.2023).

Below you will find an overview of other areas of application for robotics and Internet of Things:

- **Automotive.** In cars, devices can give information about things like traffic or car health and send this information to a data cloud where they are analyzed. Example: a self-driving car that can take you where you want to go. A car that alerts the driver if there's a problem with the engine.
- **Logistic Robots**. Logistic Robots are used to sort and store goods. They can also help with picking and packing products.
  Example: in a warehouse the goods are transported by a warehouse robot from and to the delivery vehicle

- **Retail.** In stores, devices can keep track of what's in stock. Robots can help move things in warehouses or deliver things to customers. Example: A device that alerts a store owner when they're running low on a product, and a delivery robot bringing a package to your home.
- **Healthcare.** IoT and robotics in Healthcare: In hospitals, special devices like heart rate monitors can send information directly to doctors. Example 1 (IoT): A patient wearing a heart rate monitor at home that sends updates to their doctor in real-time. Example 2 (robotics): In medical robotics, robots are used in surgery to perform precise and minimally invasive procedures. They can also help with patient rehabilitation and care.
- **Smart Cities.** In cities, devices can control things like traffic lights or garbage collection. Robots can do jobs like watching for danger or fixing things. Example: Traffic lights that change based on real-time traffic conditions, and a robot fixing a broken street light.
- **Smart houses and services.** In houses, IoT devices can control things like lights or temperature. Example 1 (IoT): A smart thermostat can change the temperature based on your preferences, and a robot vacuum cleaning the floors. Example 2 (robotics): Service robots are used in a variety of settings, including hotels, restaurants, and hospitals, to perform tasks such as cleaning, delivering food and drinks, and receiving and entertaining guests.
- **Military and security robotics.** Robots are used in military applications to perform tasks such as reconnaissance, defusing bombs and rescuing people in dangerous situations. They can also help monitor borders and public places.

Activity: Explore application fields of Robots

You will find a comprehensive overview of the range of applications of robots with numerous examples at https://robotsguide.com/robots/.

Lesson 1.2.2. Technical feasibility, market feasibility, and financial feasibility

As you have seen, robotics and the Internet of Things can be used in almost all areas of life to enable improvements and thus solve a wide range of problems. This raises fundamental questions about what is feasible and desirable from the point of view of technology, economy, and society. And there is also the question of where the limits of these technologies lie. There are no general answers to these questions. Technology, economy, and society are constantly evolving. The discussion about these questions must therefore be conducted again and again by all stakeholders, citizen and political decision-makers, and a social consensus must be reached.

Not least for this discourse, we need deeper knowledge of feasibility from the perspectives: People, technology and economy. Let us therefore take a closer look at the three levels in the following chapter.

Technical feasibility

When we talk about the technical feasibility of robots, we're considering whether it's possible to design and build a robot that can perform a specific task successfully, safely, and efficiently. Several elements influence the technical feasibility of robots:

- **Hardware.** This includes the robot's physical body and components like motors, sensors, and actuators. The hardware needs to be robust and durable, able to perform the task without breaking or wearing out too quickly.
- **Software.** This involves the programming that controls the robot's actions. It needs to be smart enough to handle the task and respond to any unexpected situations. It's not just about the main task - the robot also needs software to handle things like navigation, obstacle avoidance, and safety protocols.
- **Power.** Robots need an energy source. The robot's power requirements will depend on its size, the complexity of its tasks, and how long it needs to operate between charges or refueling. Energy efficiency is a big part of robot design.
- **Communication.** Many robots need to communicate with other systems, whether it's a central computer, other robots, or the Internet of Things. They'll need the right kind of networking and communication protocols to do this.

Financial feasibility

A robot needs to be cost-effective. That means the benefits gained from using the robot need to be greater than the costs of designing, building, maintaining, and operating it. As the term **Financial feasibility** already intends, there are two main factors to consider **costs** and **benefits**:

Costs: On the one hand, the use of robotics causes costs for the operator on various levels:

- **Initial Purchase Price.** Robots, especially advanced ones, can be expensive to purchase. The type, size, functionality, and capability of the robot will strongly influence the costs.
- **Installation and Integration Costs.** Getting the robot up and running may involve costs for installation, integration into existing systems, and possible infrastructure changes.
- **Maintenance and Repair Costs.** Robots require regular maintenance to keep them functioning optimally, and they may occasionally need repairs. The complexity of the robot impacts these costs.
- **Operational Costs.** These are the ongoing costs associated with powering the robot and any necessary supplies or consumables it uses.
- **Training Costs.** Employees may need training to operate, supervise, or work alongside the robot.

Benefits: On the other hand, users benefit from Robotics in several ways:

- **Productivity Increase.** Robots can often perform tasks faster or more accurately than humans, leading to increased productivity. This can result in more products produced, fewer errors, and improved customer satisfaction.
- **Labor Cost Savings.** Robots can perform tasks 24/7 without breaks, sick leave, or holidays. They can also undertake dangerous or monotonous jobs, potentially reducing labor costs and health and safety issues.
- **Lifespan of the Robot.** Robots have a certain lifespan or service life after which they may need to be replaced. Longer lifespan increases financial feasibility.
- **Resale Value.** If the robot has a good resale value once it's no longer needed, this can also enhance its financial feasibility.

Market feasibility

Whether a new technology will be successful in the market, depends on many factors. For robotics, the following factors play a key role:

- **Market Need.** There must be a demand or need for the specific application of robotics being offered. This could be a brand-new application (e.g., filling a market gap), or an existing area where the robot can perform tasks more efficiently or cost-effectively.
- **Target Audience.** It's important to understand who will buy and use the robot. This could be businesses in a specific industry, consumers for personal use, or institutions like hospitals or schools.
- **Competition.** Other companies also offer similar robotic solutions. Therefore, it's crucial to know the competition and differentiate oneself from them with a unique selling proposition.
- **Regulatory Environment.** Depending on the industry, certain regulations can influence the use of robots. These regulations can affect the design, functionality, safety measures, and even the disposal of robots.
- **Technological Developments.** The pace of technological change can impact the market feasibility. If the technology advances quickly, a robot can become outdated rapidly.
- **Pricing Strategy.** The price for your robot should be appropriate for the target market. This includes considering the customers' willingness and ability to pay and ensuring that the price covers production and marketing costs and leaves a reasonable profit margin.
- **Sales and Distribution.** It's crucial to use the right distribution channels to sell and distribute the robot.
- **Support and Services.** Complex products like robots require highly qualified customer service, skilled maintenance, and repair services, which often cannot be performed by the user themselves. So, this service has to be guaranteed by the manufacturer and supplier of a robotic product.

Lesson 1.2.3 Ethical and social implications of IoT and Robotics

As we have seen in Lesson 1.2.2, there are also questions about the social desirability and limitation of new technologies such as robotics and the Internet of Things. These questions are important because IoT and robotics, in addition to many advantages, can also bring many disadvantages for people and society. This gives rise to questions about personal rights, health, data security and fundamental ethical questions about the relationship between people and technology in society.

A) Social and environmental disadvantages:

- **Societal and economic divides:** Not everyone has the same access to IoT or robotics technologies. This can lead to a widening of the digital divide between those who have access and those who do not, which can increase societal and economic divides.
- **Dehumanization**: The increasing use of robots in roles traditionally filled by humans, like caregiving, could lead to issues like decreased human interaction and loss of personal touch.
- **Job Displacement**: Robotics can replace human labor in certain sectors, leading to job displacement. This raises ethical questions about the responsibility of organizations and societies to those whose employment is threatened.
- **Environmental Impact**: The production, use, and disposal of IoT devices and robots can have significant environmental impacts.

B) Ethical challenges

- **Privacy**: With the proliferation of IoT devices collecting and sharing data, privacy becomes a major concern. IoT devices could collect personal information without the user's consent or awareness.
- **Manipulation:** IoT devices can be used to manipulate user behavior, often without the user being aware of it.
- **Human** Dependence: Increased dependence on IoT and robotics may decrease our ability to perform tasks without technology, potentially reducing skill sets and fostering over-dependency.
- **Responsibility and Liability:** In case of accidents caused by robots or IoT devices (like self-driving cars), determining responsibility can be challenging.
- **Bias and Discrimination:** Algorithms used in IoT and robotics can replicate or exacerbate societal biases if not carefully designed and tested.

C) Technical and security related disadvantages

- **Privacy issues:** IoT devices and robots collect a lot of data, and that can cause privacy issues.
- **Data & physical security:** IoT devices and robots can also be vulnerable to hacking, which causes risks to data security and our physical security. Many of these systems don't have very strong security standards, which makes them even more vulnerable (see below).

Example: IoT devices can be vulnerable to hacking

Right now, there are several harmful actions that people take to mess with the safety and privacy of IoT devices and robotics. One new way that's coming up is the attacks that abuse the use of sensors on robots or IoT devices. These devices are easy targets because there's not a good way to protect their sensors from misuse by applications. When people take advantage of these sensors (like motion sensors, rotation sensors, microphones, light sensors, etc.), they can steal info from the device, put harmful software on it, or make it do something harmful.

Principles of ethics for robots and the Internet of Things

To address these challenges, we need clear rules and guidelines. We are thinking about a set of rules to guide how these technologies should be designed and used to make sure they're beneficial and fair for everyone. Here are some ideas of those rules:

- **Respect for Autonomy:** This means tech should empower users, not undermine their independence. You should be in control of your data, and IoT devices should be designed with your permission in mind.
- **Beneficence:** robots and IoT devices should be designed and used to do good and improve life without causing harm.
- **Privacy and Security:** This is very important. Your data needs to be protected from people who shouldn't have it. This means using secure protocols and encryption, and collecting as little data as possible, in a transparent way, and keeping it anonymous if we can.
- **Justice:** Tech shouldn't create or increase inequality. Access to IoT and robots shouldn't be limited to the privileged few, and we should address issues like job losses due to automation.

- **Responsibility and Transparency:** When things go wrong, we need to know who's responsible. IoT device and robot makers should be held accountable for their products, and the decision-making processes, especially with AI, should be transparent.
- **Sustainability:** We should think about the environmental impact of creating, using, and getting rid of these technologies.

The first robot rules by Isaac Asimov

At the end of this chapter, let's listen to the Russian-born American science fiction author Isaac Asimov (Figure 1.2.10), who had written the first basic rules for robot in a human society.

Figure 1.2.10: Isaac Asimov (Robotic Industries Association).

Asimov first used the word "robot" in his short story "Runabout" in 1942. Asimov was optimistic about the role of robots in human society, portraying them as helpful servants. Asimov proposed three "robot laws" that his robots, as well as many other science fiction robot characters, followed (drawn on Kräußlich, 2022):

> ***Law One:*** *A robot may not injure a human being or, through inaction, allow a human being to come to harm.*
>
> ***Law Two:*** *A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.*

> ***Law Three:*** *A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.*

Why the EU Parliament is calling for laws for robots

According to Julia Reda from the German Pirate Party, robots are playing an increasingly important role in our everyday lives. If all of machine's decisions can no longer be directly traced back to the actions of a person, it must be clarified who is liable if something goes wrong (Spiegel Netzwelt, 2017). The European Parliament has been discussing regulations for the use of robotics and the Internet of Things for a long time. In a resolution from 2017 passed by a large majority, it called for comprehensive laws for robots and artificial intelligence at EU level entitled *REPORT with recommendations to the Commission on Civil Law Rules on Robotics*.

Unresolved liability issues

In May 2016, an autonomously controlled vehicle from Tesla caused a fatal accident in the US state of Texas. The car's sensors did not detect a truck swerving in autopilot mode. This is one of the reasons why Parliament is now calling for EU-wide security rules to be created. The resolution states that "harmonized rules are urgently needed," especially when it comes to autonomous driving.

To date, there are practically no civil law laws in the EU: Who is liable in such accidents? The status of robots is also not defined: what ethical rules apply to them? Do they have rights? In its report, Parliament calls for long-term consideration of "creating a special legal status for the most autonomous robots as "electric people'" in order to differentiate them from humans. "A robot is not a human being and never will be," clarified Mady Delvaux from Luxembourg, the rapporteur responsible for the EU Parliament (Spiegel Netzwelt, 2017).

European AI Act

Since March 2024, the European Union has been the first legislator to set clear rules for the use of artificial intelligence (AI) and thus also for robotics and Internet of Things applications in the so-called Artificial Intelligence Act (2024). The law classifies the rules according to the risk that artificial intelligence can pose. The AI Act completely bans some particularly sensitive applications. AI systems, and therefore also robots and IoT systems, are regulated based on their risks. Some systems are completely banned and others must meet requirements in order to be used. All remaining systems can initially operate without further restrictions, although the Commission reserves the right to expand the list of regulated systems if the risk is sufficient.

The central subject of the regulation is high-risk AI systems that must meet comprehensive documentation, monitoring and quality requirements. The users and providers of high-risk AI systems bear the brunt of the requirement.

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TOPIC 1.3. Functionality of IoT Devices and Robots

Figure 3.1. Pexels (Pavel Danilyuk, https://www.pexels.com/de-de/foto/frau-technologie-blume-festhalten-8438980/).

Learning objectives

After completing this topic, the students will be able to describe the functional components of an IoT Architecture and of a robot, understand how IoT systems and robots regulate themselves, how robots perceive their environment and react.

Topic content

VIDEO 1.3. Functionality of IoT Devices and Robotics [*duration 5:22 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/64424/course/section/2415/Topic%203%20Functionality%20of%20IoT%20Devices%20and%20Robots.mov

Lesson 1.3.1. The Components of an IoT Architecture

As we already know, the Internet of Things (IoT) describes the network of physical objects, “things, that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet” (Oracle, 2023).

Four-layer-IoT-Architecture

To better understand how the Internet of Things works, let's look at a common model for it. There is no universally accepted model for IoT that most experts adhere to. What most models have in common is that they are built in a so-called layer architecture. Depending on the task, the complexity and number of layers can vary. However, a four-layer structure is generally accepted and most commonly used. It is also referred to as a four-layer IoT architecture.

Figure 1.3.1 – 1.3.2 show the four layers of a typical IoT architecture within its components and processes:

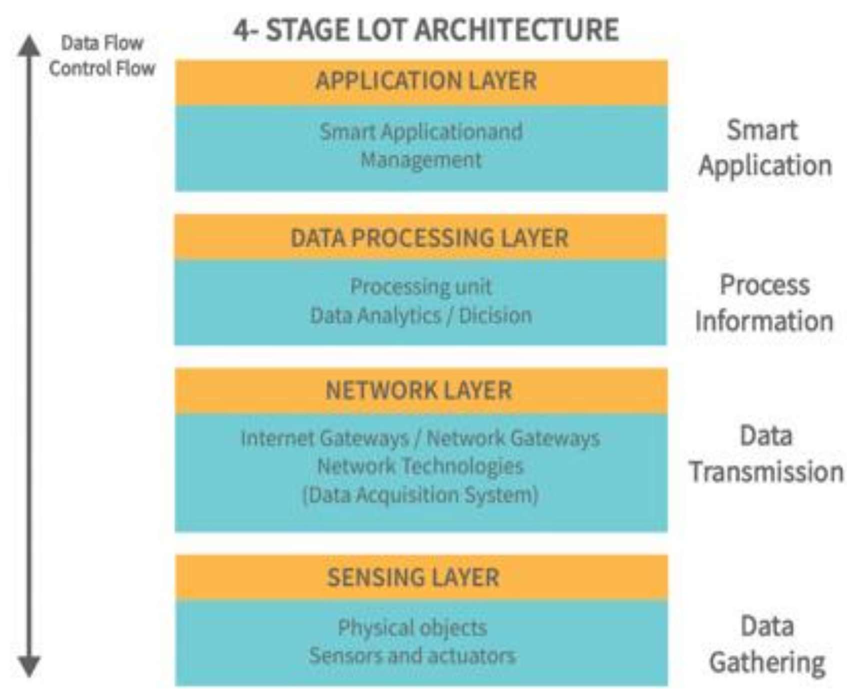

Figure 1.3.1. Four layers of an IoT architecture (Interviewbit).

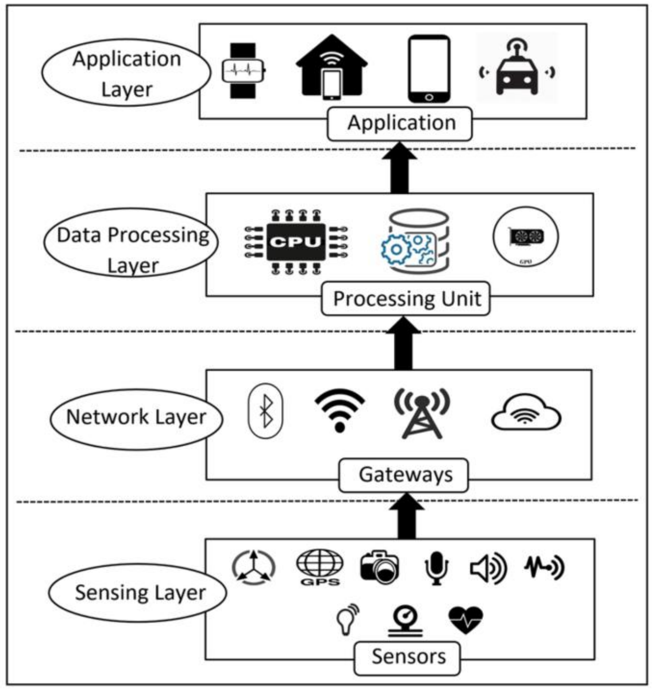

Figure 1.3.2. IoT Architecture Layers and Components (Sikder et al., 2018).

Learn more about IoT architecture from the sources listed above.

- **Things/Devices**. These are the physical objects embedded with **sensors**, software, and other technologies that enable them to collect and exchange data. Examples include smart appliances, wearable devices, and industrial machines.
- **Gateways and Networks.** These are the communication systems that enable data transfer between the IoT devices and the cloud. This could involve various types of networks like Wi-Fi, cellular, Bluetooth, or other IoT-specific networks like LoRaWAN. Gateways can help bridge the communication between different types of networks and devices.
- **Data Processing.** In this layer, the data from the sensors is analyzed. Based on the analysis, appropriate decisions are then forwarded to the devices involved. **For data processing two different locations can be used:**
    - **Edge IT.** This is the layer of **computing** resources that is located close to the IoT devices, often serving as an intermediary between the devices and the cloud. Edge computing can enable more efficient data processing by reducing the amount of data that needs to be sent to the cloud and providing quicker response times.

    - **Cloud IT.** The cloud provides large-scale **storage** and **computing** resources for the IoT. A cloud solution is often used for this. It can be used for more complex data processing tasks, long-term data storage, and hosting of applications and services.

- **Applications.** Applications are the software programs that use the data from the IoT devices to provide some form of value to the end-users. This could be anything from a mobile app that lets a user control their smart home devices, to an enterprise-level application that uses sensor data for predictive maintenance in a factory.

Each layer plays a crucial role in enabling the interconnected data flow and functionality of an IoT system. Remember, while these are the core elements, specific IoT architectures may vary depending on the application, industry, or specific use case. Based on this, robots can be a part of an IoT System. We will come back to this in the next chapter.

Lesson 1.3.2. The functional components of a robot

Typically, robots can do three things: they **sense**, they **compute**, and they **act.**

Robots seem to have similar components that we know from an IoT. Remember: an IoT also includes **Sensors** (embedded in objects), **Data Processing** (computing) and **Applications** (action part).

Sense, compute and acting

All these capabilities of a robot require mechanical hardware such as sensors or motors, computer hardware and, of course, software. These three capabilities vary from robot to robot, but essentially, they always have these three abilities:

- **Sensorics.** The sensor part, or sensorics, can be any kind of sensor or measuring device that captures information from the environment. To sense the world, some robots use simple devices, like an obstacle-detecting sonar, while other robots rely on multiple sensors, including cameras, gyroscopes, and laser range finders.
- **Data processing.** The computer part, or data processing**,** can include anything from a small integrated electronic circuits and processors to a powerful multicore processor or even a cluster of networked systems that, due to their size, no longer find space in the robot but are connected to the robot via a cloud.
- **Actuators.** The action part, or actuators, basically includes abilities to move around or manipulate things. Some abilities are highly specialized for certain tasks. Others are universally designed for different requirements.

Gateway

But what about the **gateway?** Remember: gateways are important components for IoT systems. Does that also apply to a robot? It all depends: when a robot communicates with computers, data storage devices or other applications, this happens via a network connection, a gateway. This can be a local network cable or a WiFi connection. Or the robot connects via the Internet. In this case, the robot would be a device in an IoT.

Main Hardware components of robots in principle

To give an example for this, let's have a look at our small robot mBot (Figure 1.3.3). We can identify these three types of capabilities: All data are processed in the **micro-computer** on the vehicle roof. Two ultrasonic **sensors** and an infrared sensor are placed on the front and drivers and wheels, the **actuators,** are mounted under the body. All components are **interconnected** with cables to transfer data and/or energy.

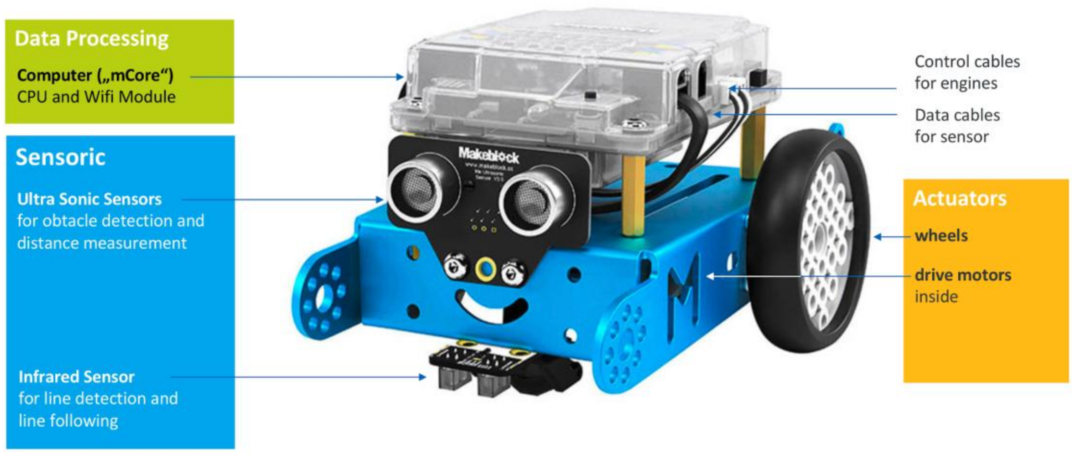

Figure 1.3.3. Main components of robots in principle (Makeblock).

Lesson 1.3.3. The feedback loop - how robots and IoT systems regulate themselves

Self-regulated but not autonomous

A key feature of IoT devices and robots is their ability to self-regulate and control their activities. For this purpose, the sensors, data processing and actuators work together in a so-called **feedback loop**.

The term feedback loop usually refers to the continuous process where a robot collects data from its sensors, processes this data to make a decision, and then performs an action based on that decision. It then uses the result of that action as input (feedback) for the next cycle of decision-making and activity.

Robots and autonomy

In this way robots (with some limitations) can make their own decisions to accomplish the tasks we give them. Nevertheless, autonomy in robotic systems varies greatly depending on the complexity of the system and task. Some of them may only perform very specific, pre-programmed tasks while others, like autonomous vehicles, are designed to handle a vast array of complex scenarios.

The gateway – connection to more resources and skills

The more complex data robots must process, the more resources they require, which they access through a network. This network can be either a wired connection (e.g., Ethernet) or a wireless connection, such as a mobile connection (e.g., 5G) or a Wi-Fi connection. These so-called gateways enable the system to connect to supporting services and resources on external computer systems. If these computers are nearby, we call it edge computing. If they are far away in a data center, we usually speak of cloud computing.

Four different types of Network connections for IoT had been invented:

- Cellular networks like LTE-M, NB-IoT, etc.
- LAN/PAN like Bluetooth, WiFi, etc.
- LPWAN like LoRaWAN, Sigfox, etc.
- Mesh protocols like RFID, ZigBee, Z-wave, etc.

Example: autonomous car

Figure 1.3.4. Autonomous race car (Flickr).

An autonomous vehicle like a self-sealing car (Figure 1.3.4) needs a large amount of data in real time to make appropriate and safe decisions in fast traffic. For this purpose, the vehicle is continuously in contact with sensors and application programs, some of them on board (like for detecting speed, direction, route, other vehicles and traffic users, obstacles, traffic signs and much more), some of them outside, in a cloud e.g. providing data about rolling and stationary traffic, traffic jams, road closures, weather, etc. From all this data the vehicle generates a detailed picture of the situation as a decision basis. Therefore, it is important that the data collection, transmission, as well as the data processing, is secure, fast, and uninterrupted. There are often additional requirements depending on the application, like the importance of data accuracy, the power efficiency, and the sustainability of the device.

The feedback loop as a process

As we have seen before, the feedback loop is a control loop of continuous measuring, data collecting, processing, and resulting actions. Figure 1.3.5, based on a typical control circuit, shows this process:

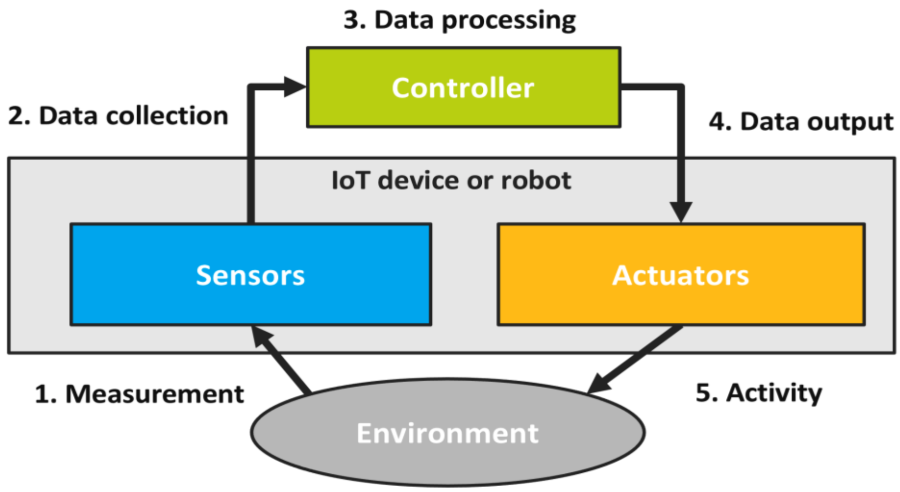

Figure 1.3.5. Model of a control loop (Shaw, 1995).

The diagram above shows a repetitive cycle, a typical control loop where the robot works continuously. On closer inspection, the following phases can be described:

1. **Measurement:** it all starts with the sensors. These devices measure physical and chemical conditions from their environment. This could be as simple as a temperature sensor, a distance measurement or as complex as a full video feed.
2. **Data collection:** the data collected by these sensors are converted into digital data. This data is then sent to the data-processing component. This part can be located onboard or external, on a computer nearby or in a large distance in a remote data center. The transmission path for the data is called gateway and network, that can i. e. differ between wire, WI-FI or mobile Connection.
3. **Data processing**: once the data is collected and sent to the network, some sort of processing is required to turn it into useful information. This could be done in the cloud, on the periphery of the network, or in some cases directly on the device itself.
4. **Data output and activity**: here are multiple output modes possible:
   - The information is stored in a database for later uses.
   - The information is presented to the user. This could be a notification sent to a smartphone or data displayed on a dashboard.
   - The output leads to an activity of actuators such as turning on the heating when the temperature drops below a certain level.

A feedback loop is a fundamental component of robotic systems and in the IoT. It allows the system to adjust its actions based on its internal state and its environment.

Feedback loop in an example

Here's an example how a feedback loop works: Let´s observe our mBot going around an obstacle operating the following steps (Figure 1.3.6):

1. **Input or Action:** First, the mBot performs a certain action. In this case, it's moving in the direction to achieve a given goal.
2. **Measurement:** During or after the action, the robot measures the effects of this action. To do this, e. g. it uses ultrasonic sensors that measure the distance to an obstacle.
3. **Comparison:** The measured values are compared with the desired target values. For example, if the robot is supposed not to fall below a certain distance to an obstacle, it is checked whether it has reached that set-point.
4. **Correction:** If the set-point has been reached or exceeded the robot's action is corrected accordingly. In this case the robot steers in a different direction to avoid the obstacle and then he pursues his goal again.
5. **Repetition:** This process repeats constantly. This way, the robot can continuously adapt and improve its actions.

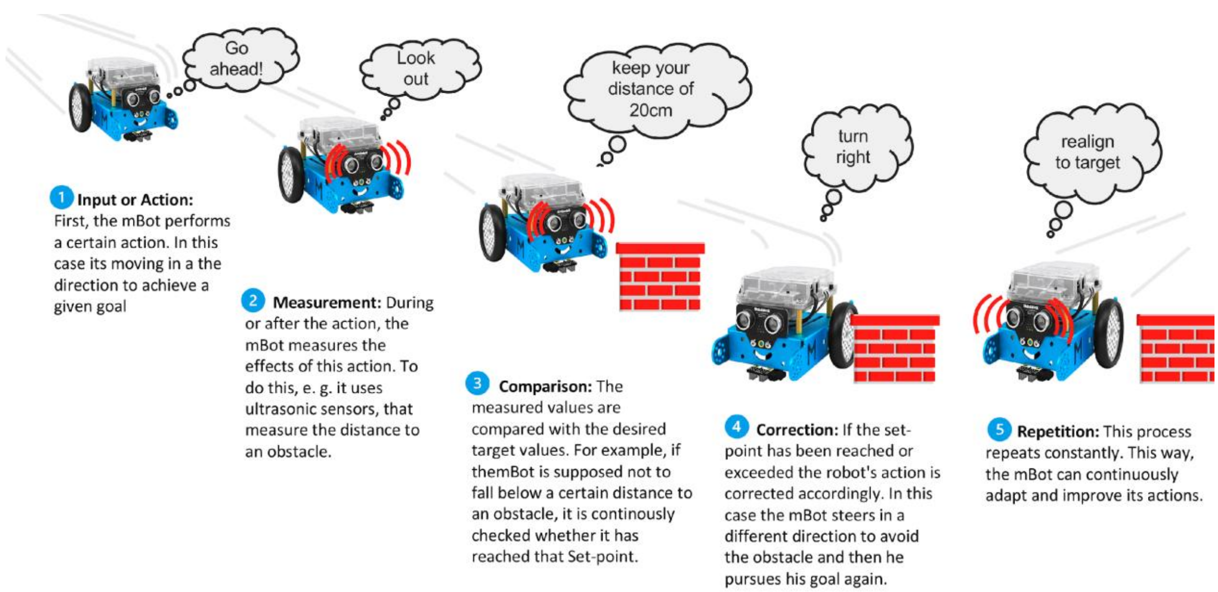

Figure 1.3.6. Feedback loop of a small autonomous vehicle (Makeblock).

These feedback loops are an essential part of autonomous systems and enable robots to perform tasks with high precision and efficiency.

Lesson 1.3.4. Sensors: how robots perceive their environment

On the Internet of Things as well as in robotics, sensors are crucially important. Put simply, sensors can be compared to the sensory organs of living beings. Of course, in some respects they cannot match their capabilities, in some respects they are even better than biological sensory systems. Robots and IoT systems use them to establish contact with the outside world. First, let's take a closer look at the different types of sensors and later explore some actuators.

15 and more types of sensors

A sensor is a device that detects physical or chemical properties such as temperature, pressure, light, noise, or even the presence of a specific type of gas in the environment and converts this information into a signal that can be read or understood by a data processing unit or a gateway. Also, complex sensor signals like audio and video data can be processed. Essentially, sensors are tools that help us measure, detect, and understand the world around us by converting physical phenomena into usable data. Depending on the application and purpose, a variety of sensors can be used. Here are some examples.

Optical sensors

1. **Light sensors:** Measure the intensity of light. Used in automatic street lighting, digital cameras, and greenhouses to optimize light conditions.
2. **Infrared sensors:** Measure heat emitted by objects. Used in night vision equipment, weather forecasting, and thermal efficiency analysis.
3. **Image sensors:** Convert optical images into electronic signals. Used in security cameras, digital cameras, and medical imaging devices. The image signals can be processed by artificial intelligence, for example, to recognize objects, environment, individuals, behavior, and other characteristics.

Environmental sensors

1. **Humidity sensors:** Measure moisture levels in the environment. Used in weather stations and agriculture to control irrigation.
2. **Moisture sensors:** these are used in agricultural IoT applications to monitor soil moisture levels and control irrigation.

3. **Gas sensors:** Detect different gases in the environment. Used in air quality monitoring, leak detection in industries, and home safety systems for detecting harmful gases.
4. **Pressure sensors:** Detect pressure changes in liquids or gas. Used in car tire pressure monitoring, weather forecasting systems, and in industrial environments to monitor processes.
5. **Temperature sensors:** Measure heat or cold and convert it into a readable format. Used in home automation systems, weather monitoring, healthcare, and industrial processes.

Acoustic and impulse sensors

1. **Acoustic sensors**: these are often used in security systems to detect unusual sounds or breaks. They can be used for voice recognition for human-robot interfaces.
2. **Ultrasonic sensors**: Use sound waves to measure distance. Used in robotic obstacle avoidance, car parking sensors, and level detection in tanks.
3. **Vibration sensors**: register vibrations and mechanical impulses i.e., to analyze the operation of a machine.

Motion and orientation sensors

1. **Gyroscope sensors:** Measure orientation using earth's gravity. Used in navigation systems, game controllers, and drones to maintain stability and control.
2. **Proximity sensors**: Detect when an object is close without physical contact. Used in mobile devices, vehicle parking assistance, automation lines in factories.
3. **Motion detection sensors**: Detect movement in a given area. Used in security systems, automatic doors, and lighting systems.
4. **Accelerometer sensors**: Measure acceleration and tilt. Used in mobile devices for orientation, in vehicles for stability control, and in robotics for movement control.
5. **Force or load sensors**: Measure the amount of force applied. Used in robotics for grip control, weight scales, and industrial automation.

Three typical sensors in detail

Let's take a closer look at the sensors of the mBot (Figure 1.3.7). It's equipped with two types of sensors: **two ultrasonic sensors**, which are used for obstacle detection and distance measurement, and the **infrared sensor**, which is used for line detection and line following.

- The **ultrasonic sensor** emits a sound signal and measures the time it takes for the reflected sound to arrive again. The reflected time is converted into digital data and sent to the data processing unit (computer) which calculates the distance from the reflection time.
- The **infrared sensor** emits infrared light and measures the strength of the reflected light. The reflected light strength is recorded by the sensors, converted into digital data which are sent to the processing unit (computer), where the data are compared with specified values (e.g. the minimum distance to an obstacle).

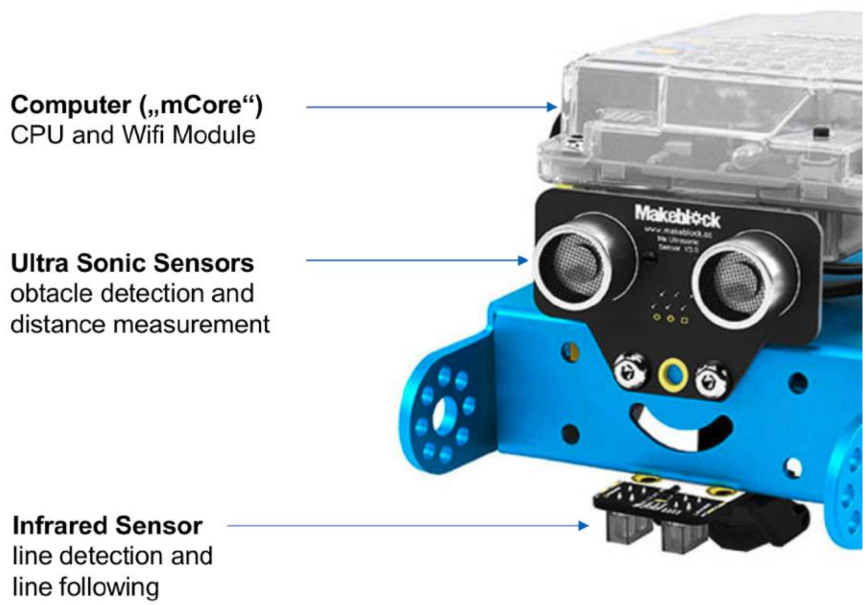

Figure 1.3.7. Sensors of the mBot (Makeblock).

Lesson 1.3.5. Actuators: how robots act in their environment

Actuators enable an IoT or robotic system to generate any output, interact with their environment and manipulate it. Put simply, actuators can be compared to the muscles and organs of living beings. And as we have already seen with sensors, they cannot keep up with all their capabilities. But in some respects, they are even much better than biological “actuators” for they are much more specialized. Here are some examples:

1. **Motors:** Probably the most common type of actuators in robotics, motors provide rotational movement and can be used for a variety of tasks, from moving a robot's wheels to controlling its arms. Different types of motors like DC motors, stepper motors, and servo motors are used based on requirements.
2. **Linear movement actuators:** These convert energy into straight-line movements and are used when something needs to be moved up and down or side to side. They can be seen in action in adjustable desks, hospital beds, or in robotics for specific types of precise movement.
3. **Complex movement actuators:** Using joints, gears and other connections, linear movement actuators can also enable complex movements such as a gripping hand. The movements can be performed with varying degrees of force. These range from very sensitive fine motions, such as those of a surgical robot during eye surgery, to enormous forces, such as those required in transportation.
4. **Solenoids:** These are electromagnetic devices that produce a mechanical output when they are electrically activated. In the IoT, they can be used in door locks, valves, or switches.
5. **Pneumatic actuators:** They use pressurized air to create motion and are often used in industrial applications for their high speed and force. In robotics, they are used in soft robots or those which need lightweight actuators.
6. **Hydraulic actuators:** They work similarly to pneumatic actuators but use a liquid like oil under pressure. They are used when high force and precise control are required, like in construction equipment or high-load robotic applications.
7. **Piezoelectric actuators:** They use piezoelectric materials that expand or contract when electric voltage is applied. These are used when high precision, high speed, and high reliability are required, such as in some micro-robotic applications.

8. **Shape Memory Alloys (SMAs**): These are materials that change shape in response to changes in temperature, electric current, or magnetic field. They're used in some specialized robotic applications where subtle and smooth movements are required.
9. **LED lights**: Although not a traditional actuator, in the IoT context, they can be used as a form of actuator responding to changes in the system – for example, changing color or intensity based on different data inputs.
10. **Audio system:** The robot can communicate with users using the audio system (loudspeaker). The user responds via a microphone (-> sensor). Using generative AI-generated speech, a robot can conduct simple conversations with the user in natural language.
11. **Video monitor:** A video display often serves as a communication interface between humans and robots. The computer uses this to send information and requests to the human user. The user can then enter their commands to the computer via the same display.
12. **Sound system.** A so-called odor synthesizer can, for example, generate and emit odors. This is sometimes already used in the service sector.

Conclusions

In this chapter, you learned about the functionality of IoT devices and robotics.

It is important to understand that systems, based on the Internet of Things, are structured in a specific architecture. An IoT architecture consists of different layers including devices with embedded sensors, networks or gateways, processing units in form of any computer and applications and actuators.

The functional components of a robot are quite comparable to this. So, a robot connected to the Internet via a gateway can be classified as an IoT device.

IoT systems and robots regulate themselves using their components for operating a continuous feedback loop. Repeating this loop, robots interact with their environment and do the jobs we give them.

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TOPIC 1.4. Development of IoT and robot-based solutions

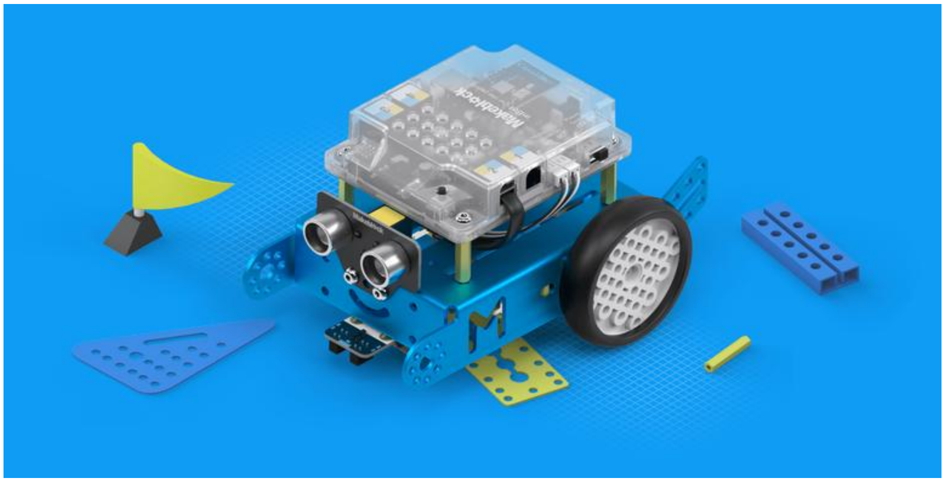

Figure 1.4. Robot-based solutions (Makeblock)

Learning objectives

After completing the topic, learners will gain the ability to outline the development process, which includes analysis, design, ideation, implementation, and optimization of problem solutions using robotics and/or IoT. They will also understand basic coding and no-code programming methodologies, data analysis, computer visualization, and machine learning.

Topic content

VIDEO 1.4. Development of IoT and Robot based Solutions [*duration 7:05 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/64424/course/section/2416/Topic%204%20Development%20of%20IoT%20and%20Robot%20based%20Solutions.mov

Lesson 1.4.1. Development process of a robot

IoT systems and robots are complex systems to which special requirements apply in terms of human, ethical, social, technical, legal and economic issues. Therefore, their development is an interdisciplinary challenge. Different disciplines should be involved from the early stage.

Following a standardized sequential process model, the development of a robot can be structured into the five phases: **analyze, design, implement, test & optimize, deploy.**

Have a look at this simplified development process for a robotic solution, based on a generic software development process (Figure 1). As you see, it is structured in five successive phases, which, however, do not necessarily only run through once but are repeated iteratively in some cases.

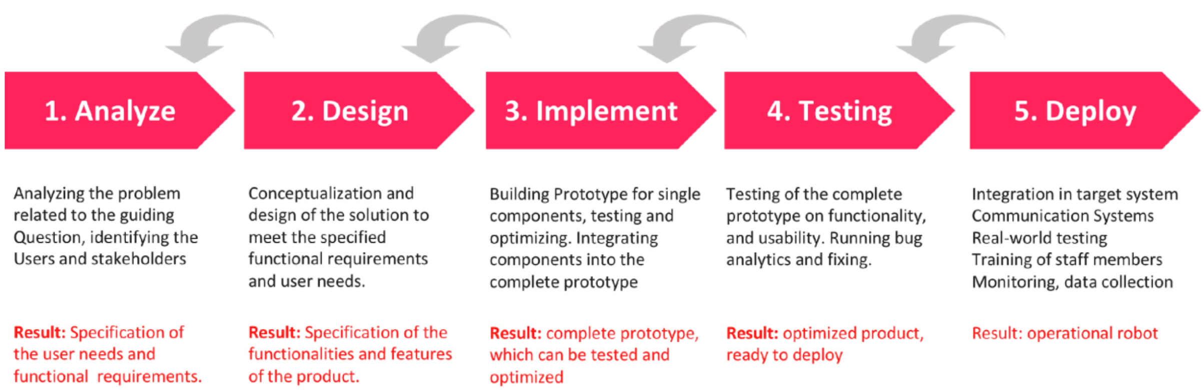

Figure 1.4.1. Sequential development process for a robotic solution, based on a software development process (Dickel 2023, Alavandhar and Nikiforova, 2017).

In the next module 5 you will start with your own project using this method!

Below, you'll find the step-by-step procedure for developing a robot.

Phase 1: Analyze the situation and define the needs and requirements

During the analysis phase, the team identifies the purpose and objectives of the robot. They conduct research to understand the problem the robot aims to solve and the involved stakeholders. This analysis involves studying user requirements, safety considerations, potential constraints, and technical issues. This includes identifying the requirements in terms of size, weight, speed, and accuracy. Also, they analyze the physical environment and conditions under which the robot will operate, such as the temperature, humidity, and dust levels. By the end of this phase, the team should have a clear understanding of what the robot needs to accomplish.

> **Result 1:** The result of this phase is a written document with the specification of functional requirements and user needs which must be considered for the solution.

Phase 2: Design of the technical concept and specification of the functionalities

In the design phase, the development team comes up with potential concepts and solutions to address the defined requirements and needs.

The team outlines the robot's architecture, key components, sensors, actuators, and other necessary hardware and software elements. Additionally, they establish a set of criteria to measure the robot's success in meeting its objectives. Ideas are shared, evaluated, and refined to identify the most feasible and effective approaches. This phase encourages innovative thinking and allows the team to explore different possibilities before proceeding further.

> **Result 2:** The outcome of this phase is a comprehensive design specification outlining the functionalities and features of the product. Additionally, it delineates the technological concept upon which the solution will be built.

Phase 3: Implementation of the robot components and integration in a prototype

In the implementation phase, the team starts building the robot by assembling the hardware components and developing the software that controls its actions. At the beginning, several prototypes are developed in order to test and optimize individual functions, such as locomotion or sensor technology. Later, a complete prototype is built in which all systems are integrated and can be tested. Prototyping plays a crucial role during implementation, as it allows the team to test and validate their ideas in a real-world setting. The team follows an iterative approach, continuously refining the robot's design as they gain insights from testing and feedback.

> **Result 3:** The result of the phase is a complete prototype of the robot, which can be tested and optimized.

Phase 4: Testing and optimization of the prototype, bug analytics and fixing

Once the initial implementation of the prototype is complete, it is important to optimize it. This means making sure that it works as efficiently as possible, and that it meets the requirements. Here, the team fine-tunes the robot's performance, addressing any issues or inefficiencies that arise during testing. Optimization may involve improving the robot's algorithms, enhancing its responsiveness, or reducing its power consumption. This may involve making changes to the design, the software, or the sensors. The team may also conduct usability tests to gather feedback from potential users and make necessary adjustments based on the results. This phase is essential for ensuring that the robot operates at its best and delivers the desired outcomes effectively.

Phase 5: Deployment of the complete and tested robot

The deployment phase aims to further develop the robot prototype for its later use. For this purpose, the different stakeholders of the robot´s application are involved, and the robot is further adapted technically and functionally to its real application scenario in following directions:

Integration into target system

Once the robot is tested and optimized successfully, next the robot is integrated into the target environment, which involves adapting its systems to the specific operating conditions and fine-tuning its behavior. Calibration, sensor alignment, and data synchronization are undertaken to enable seamless interaction with the surroundings.

User interfaces and communication systems

Additionally, user interfaces and communication systems are established to allow humans to interact with the robot effectively. This step may involve developing intuitive control interfaces and implementing remote monitoring and commanding capabilities.

Real-world testing

Once the robot is ready for operation, extensive real-world testing takes place to validate its performance under different scenarios and conditions. This iterative testing process helps uncover any potential shortcomings, leading to further refinements and enhancements. The robot's autonomous behaviors are assessed to ensure it can detect and avoid obstacles, adhere to safety protocols, and prevent unintended interactions with humans.

Training of staff members

Moreover, during deployment, staff members are trained to operate and maintain the robot competently. Proper training guarantees that the robot is operated efficiently and safely, while maintenance protocols ensure its reliability and longevity.

Monitoring and data collection

Lastly, post-deployment monitoring and data collection are initiated to evaluate the robot's performance and gather insights for continuous improvement. Feedback from users and operators further guides future enhancements and updates.

Success factors for the robot development

As we have seen, the development of a robot is a long and complex process, but it is also a very rewarding one. The development process of a robot involves several distinct phases, each with its own set of tasks and objectives.

Throughout the entire development process, collaboration and communication among team members play a crucial role. Regular reviews and feedback sessions facilitate early issue identification and resolution, ensuring the development of a successful and well-functioning robot that fulfills its intended purpose. By following this structured approach, robot developers can create innovative and efficient robots that serve various applications and industries.

Additional tips for developing a robot

- Involve the users from the beginning to meet their requirements.
- Use a variety of tools and resources to help you with the design and implementation process. Apply simple techniques like post-its, mapping, card boxing, Lego or role play.
- Get feedback from experts and other stakeholders throughout the development process.
- Be prepared to make changes to the design as needed.

- Test the robot thoroughly at each stage of development before releasing it to the public.
- Develop and test software partly but wait with final programming until the specifications are clear.

Lesson 1.4.2. Code-based programming languages such as Python or C++

Robot programming involves the use of various code-based programming languages, each offering specific advantages depending on the application and platform. They allow developers to create instructions that control the behavior and movements of robots. Commonly used languages in robotics include C/C++, Python, Java, and ROS, but also others. Two commonly used code-based programming languages for robotics are Python and C++.

Python

Python is a popular choice for programming robots due to its simplicity and readability. Its human-readable syntax makes it easier for beginners to understand and write code.

Many robotics frameworks and libraries offer Python support, making it convenient for developers to access pre-built functions and modules for robotic applications.

Python's versatility also enables users to handle other aspects of robotics, such as data processing, machine learning, and computer vision.

Below (Figure 1.4.2) you can see a part of a simple Python script for a sensor routine of a robot that reads data from a distance sensor and reacts based on the measured distance. In this example, the robot uses an ultrasonic sensor to measure distances.

```python
import time

def read_distance_sensor():
    # Simulating distance measurement
    # Replace this with actual code to read data from the sensor
    distance = 30  # Assuming the sensor measures 30 cm
    return distance

def move_forward():
    print("Moving forward...")

def turn_left():
    print("Turning left...")

def turn_right():
    print("Turning right...")

def stop():
    print("Stopping...")

def main():
    try:
        while True:
            distance = read_distance_sensor()

            if distance > 50:
                move_forward()
            elif 30 <= distance <= 50:
                turn_left()
            elif 10 <= distance < 30:
                turn_right()
            else:
                stop()

            # Pause for a short time before the next sensor reading
            time.sleep(0.5)

    except KeyboardInterrupt:
        print("Sensor routine stopped.")
```

Explanation:

The read_distance_sensor() function is a placeholder to simulate reading data from the distance sensor. In a real application, you would replace it with code that interfaces with the actual sensor and returns the measured distance.
The move_forward(), turn_left(), turn_right(), and stop() functions are just simple print statements in this example, but they could be replaced with actual robot control commands to move the robot accordingly.
The main () function contains the main routine of the robot. It reads the distance from the sensor continuously in a loop and reacts based on the measured distance. For distances greater than 50 cm, the robot moves forward; for distances between 30 cm and 50 cm, it turns left; for distances between 10 cm and 30 cm, it turns right; and for distances less than 10 cm, it stops.
The script runs indefinitely until it is manually interrupted (e.g., by pressing Ctrl+C).
Keep in mind that this is a basic example, and in a real-world scenario, you would need to implement code to read data from the actual distance sensor and control the robot's movements accordingly.

Figure 1.4.2. Python script generated with ChatGPT4 (own image).

Prompt: write an example of a short python script for a sensor routine of a robot.

C++

C++ is a powerful and efficient programming language often used in robotics when performance is critical, such as in real-time control and complex calculations.

While it has a steeper learning curve than Python, C++ allows for more direct hardware interaction and resource management, which is essential in some robotic applications.

The choice of programming language in robotics depends on factors like hardware, performance, complexity, and the programmer's familiarity. Different languages may be used together in a robot's system, and as robotics advances, new languages may emerge to cater to specific robotic needs.

Lesson 1.4.3. No-Code programming tools

Programming robots with no-code platforms offers a user-friendly and accessible approach to create robot applications. These platforms utilize visual interfaces and drag-and-drop functionality, enabling even non-technical individuals to design and control robots. The advantages of no-code programming for robots include reduced development time, cost-effectiveness, and the ability to rapidly iterate and experiment with robot functionalities. It empowers "citizen developers" within organizations, fostering collaboration between technical and non-technical team members. However, for more complex and specialized robot applications, traditional coding approaches may still be necessary. No-code programming is a valuable tool to bridge the gap between technical and non-technical users, making robotics accessible to a broader audience and accelerating the adoption of robotics in various industries.

Makeblock

Makeblock (Figure 1.4.3) is a no-code programming platform designed to introduce students and beginners to robotics and coding. If you have no experience or interest in text-based programming, here is the good message: It is a versatile platform that allows users to build and program robots and other electronic projects without the need for traditional text-based coding like C++ or Python. Instead, Makeblock offers a graphical, drag-and-drop programming interface with a block-based programming approach, where you can stack blocks to create sequences of commands that control the robot's behavior. This makes Makeblock user-friendly and ideal for beginners.

If you already have experience in text-based programming, don't worry: Makeblock also provides an interface for Python for this, which you can alternatively use at any time, even if you started in graphical mode.

The programming aspect of Makeblock is closely related to Scratch, a visual programming language developed by the MIT Media Lab.

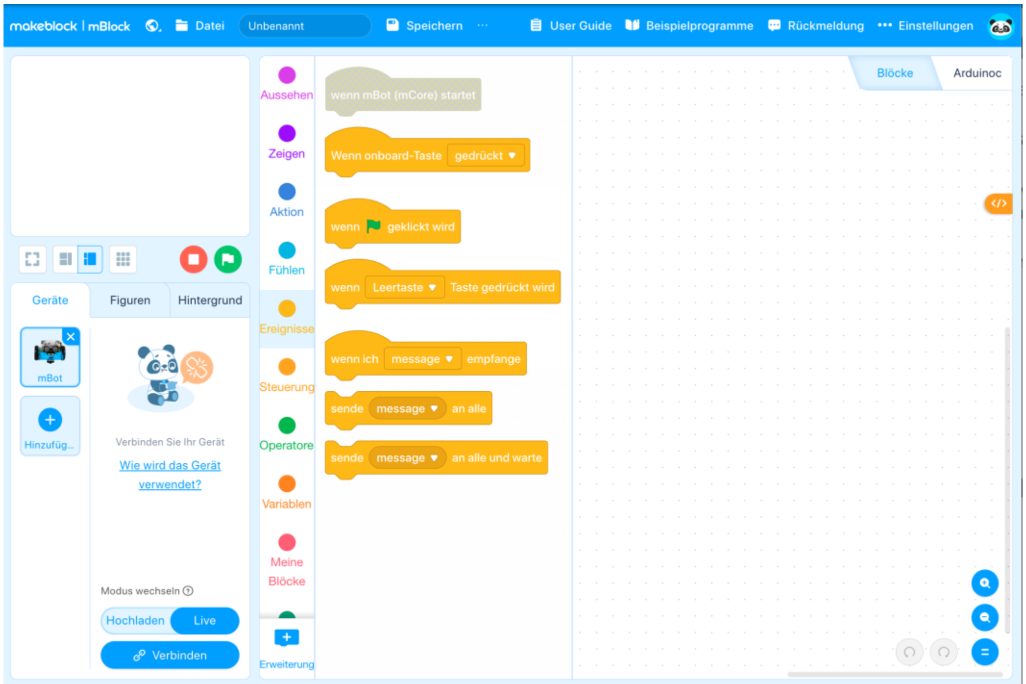

Figure 1.4.3. Interface of the no-code platform Makeblock (Makeblock, https://ide.mblock.cc/).

Makeblock-compatible hardware components

In addition to these programming environments, the Makeblock platform consists of hardware components, such as robotic kits and sensors, that users can assemble into various configurations (Figure 1.4.4). Makeblock's robotic kits provide a wide range of building options, allowing you to create different types of robots, from simple machines to more complex designs.

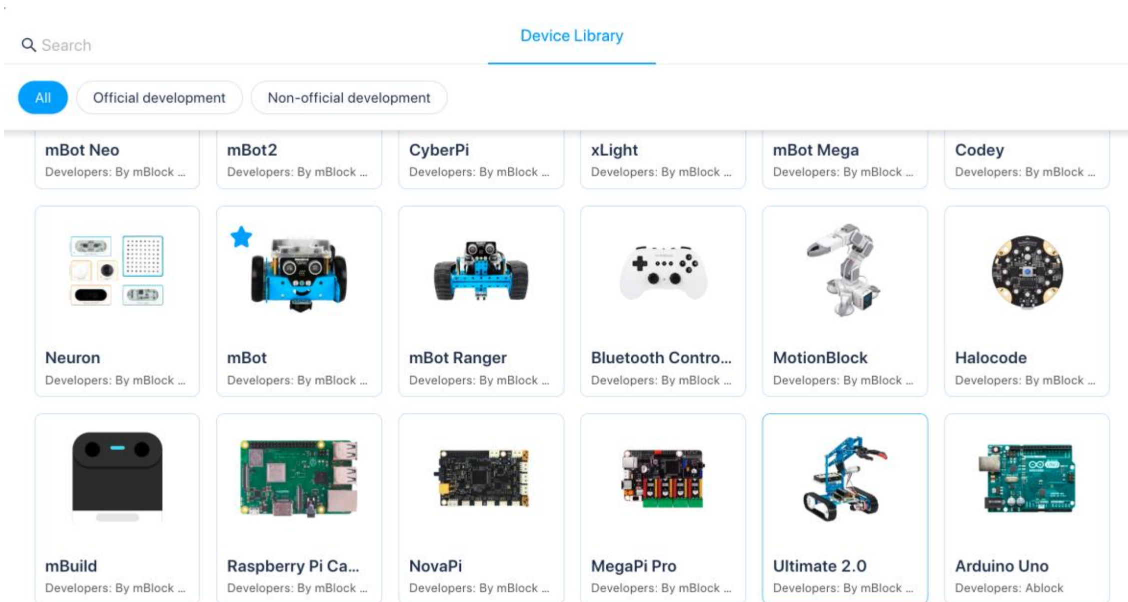

Figure 1.4.4. The Makeblock platform provides multiple hardware components like robots, maker-kits, computers and other devices (Makeblock).

Key features of Makeblock

- **Visual interface.** Makeblock uses a block-based programming language where users drag and snap colorful code blocks together, making it easy to understand and assemble code.
- **Abstraction of complexity.** By abstracting complex code syntax into visual blocks, Makeblock simplifies the programming process, making it accessible to users with little or no prior coding experience.
- **Creative projects.** Makeblock encourages creativity and storytelling. You can create characters, backgrounds, and scripts, bringing your ideas to life in a visually engaging manner.
- **Online community.** Makeblock offers an extensive online community where users can share, remix, and collaborate on projects. This fosters a collaborative learning environment and inspires users to explore others' creations.
- **Educational tool.** Makeblock is widely used in schools and educational settings to teach programming concepts, problem-solving, and logical thinking.
- **Cross-Platform compatibility.** Makeblock is available as a web-based application, as well as downloadable versions for Windows, macOS, and Linux, allowing users to access it on various devices.

- **Extensions.** Makeblock supports extensions that enable integration with external hardware and web services, expanding its functionality and potential applications.

Lesson 1.4.4 Data analysis and computer visualization for IoT and robotics

Data analysis and computer visualization for IoT

Data analysis and computer visualization are crucial for the Internet of Things (IoT). IoT generates vast amounts of data from connected devices. Analyzing this data helps understand usage patterns, optimize processes, and predict maintenance needs. Real-time analysis allows quick responses to critical events. Predictive maintenance helps prevent breakdowns. Resource management in IoT systems is improved. Data analysis detects security threats and anomalies. Computer visualization presents data visually through charts and graphs. This makes data insights more understandable. IoT users interact better with devices through visual interfaces. Visualization aids decision-making with intuitive dashboards. IoT data becomes accessible to a broader audience. Overall, data analysis and visualization are essential for maximizing IoT potential and making informed decisions.

Data analysis and computer visualization for robotics

Data analysis and computer visualization are also highly relevant for robotics. They play a significant role in optimizing robot performance, enhancing human-robot interaction, and enabling data-driven decision-making.

As described in Topic 1.3, Data analysis in robotics involves processing and interpreting data collected from various robot sensors, such as cameras, infrared or ultrasonic sensors. This analysis helps robots understand their environment, make informed decisions, and perform tasks more efficiently. For example, analyzing sensor data allows robots to navigate through complex environments, avoid obstacles, and interact safely with humans.

Computer visualization complements data analysis in robotics by representing the processed data in visual formats. Visualization techniques, such as 2D/3D maps, heat maps, and graphs, allow humans to comprehend complex robotic data more easily. This is particularly useful for robot operators and engineers who need to monitor the robot's behavior and performance.

The main difference between the two lies in their primary focus. Data analysis is concerned with processing and extracting insights from raw sensor data, while computer visualization is focused on presenting the processed data in a visually understandable format. Data analysis involves algorithms and mathematical techniques, while computer visualization relies on graphical representation methods.

Data analysis and computer visualization are both crucial for robotics. Data analysis enables robots to understand and interact with their environment effectively, while computer visualization makes the robot's data more accessible and interpretable for human users, facilitating better control and decision-making in robotics applications.

Example: 3D maps with 3D laser scanning

3D maps are three-dimensional visualizations generated by so-called 3D laser scanning (Google Lidar). The data thus obtained helps a robot, among other things, find its way around an environment. The visualization in the Figure 5 below shows the 3D topography of the stationary or moving subjects and objects.

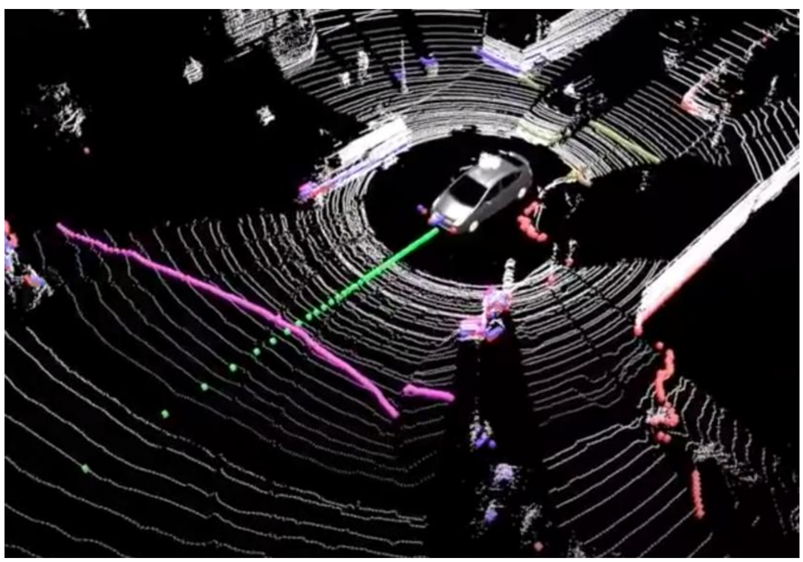

Figure 1.4.5. Video screenshot: 3D maps with 3D laser scanning (Kushleyev, 2012, 1:12).

3D laser scanning is used in IoT applications e. g. to monitor the traffic around a self-driving car. The figure 6 below shows how the self-driving vehicle uses laser scanning to scan its surroundings and detect nearby objects:

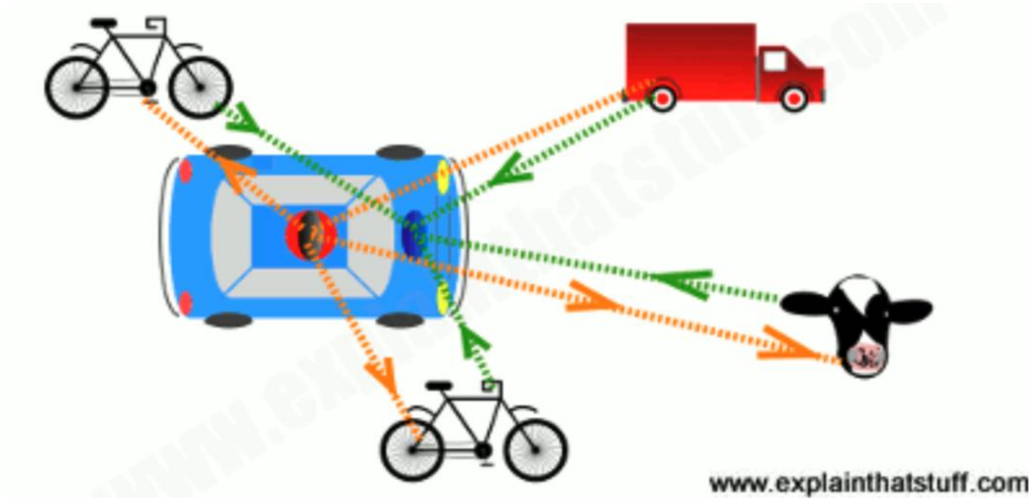

Figure 1.4.6. Self-driving vehicle uses laser scanning to detect nearby objects (Woodford, 2023).

A weak laser beam is emitted by a transmitter on the roof of the vehicle, reflected by the object and detected by a sensor on the vehicle. From the direction, strength and change in the incoming signal, a computer then calculates the position and movement of the object and the objects in relation to each other. In this way, the vehicle can make its own decisions about further driving behavior and execute reactions.

Lesson 1.4.5. Machine Learning

Machine learning is similar to human learning

Machine learning is a process similar to human learning. Consider learning to ride a bike. Initially, you may fall. But with practice, you improve. This concept of try and error mirrors machine learning.

Machines learn by Artificial intelligence (AI)

In general, machine learning is a field of artificial intelligence (AI) that empowers computers to learn and improve from experience without being explicitly programmed. It enables machines to recognize patterns in data and make predictions or decisions based on that information. Think of AI as a teacher for computers, teaching them how to perform tasks or solve problems through examples and feedback.

Learning by examples and experience

Rather than inputting specific instructions, we provide examples to the computer.

- To teach a computer to identify a cat, we show it numerous cat images. After viewing many examples, the machine analyzes patterns of how different a cat can look, and learns to recognize characteristics common to cats.
- To teach a robot how to play soccer, we train it in a situation on a virtual soccer field. After many failures and successes, the robot recognizes, for example, the movement patterns with which it can avoid a fall or get up again more quickly.

Roboschool

AI training strategies become visible, for example, in a so-called Roboschool (Figure 1.4.7). Here, a virtual agent tries to reach a goal (the pink ball) and learns to walk, run, turn, use its momentum to recover from small hits and get back up when knocked over. Watch the following training video of an AI-based robot in a Roboschool.

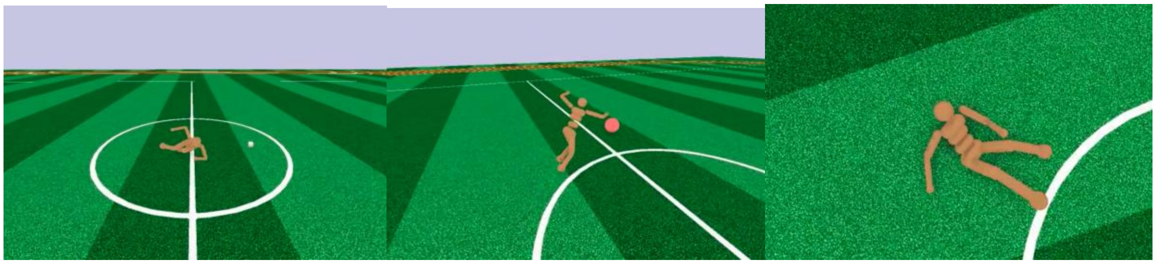

Figure 1.4.7. Screenshots from the training video of an AI-based robot (OpenAI, Roboschool).

In essence, machine learning is about learning from experiences:

- Machine learning works by identifying patterns. It starts with data. This could be numbers, words, images, or anything quantifiable.
- Algorithms are used to analyze this data. They identify patterns and make predictions or decisions without being explicitly programmed to perform the task.
- Training is a key process. The machine learning model is trained on a subset of data. The goal is to make accurate predictions or decisions.
- Validation is the next step. The model's performance is tested on a separate set of data. This helps ensure its reliability.
- Over time, the model can learn and improve. It adapts when exposed to new data. This is the essence of machine learning. It learns from past data to make accurate future predictions.

Machine learning in IoT and robotics

In the context of IoT and robotics, machine learning plays a crucial role in making these technologies smarter and more efficient. Imagine a robot that can adapt and learn from its interactions with the environment or an IoT system that can optimize its operations based on real-time data. Here's how machine learning is relevant in these areas:

- **IoT data analytics:** In the IoT, a vast amount of data is generated from connected devices and sensors. Machine learning algorithms can analyze this data to identify patterns, trends, and anomalies. For instance, in smart homes, machine learning can learn the occupants' behavior and adjust temperature settings or lighting preferences automatically.

- **Predictive maintenance in robotics:** Machine learning enables predictive maintenance in robotics. By analyzing sensor data from robots, algorithms can predict when certain components may fail, allowing for timely maintenance and reducing downtime.
- **Robot control and decision-making:** In robotics, machine learning can be used to improve robot control and decision-making. Robots can learn from their experiences to optimize movements, adapt to different environments, and improve task performance.
- **Computer vision for object recognition:** Machine learning is essential in computer vision, enabling robots and IoT devices to recognize objects and interpret visual information. This is crucial for applications like autonomous vehicles and surveillance systems.
- **Natural Language Processing (NLP):** NLP, a subfield of machine learning, enables robots and IoT systems to understand and respond to human language. It enables voice assistants and chatbots that facilitate human-robot interaction.
- **Anomaly detection in IoT:** Machine learning can identify abnormal patterns or behaviors in IoT data, helping detect potential security breaches or system malfunctions.
- **Optimization in IoT systems:** Machine learning can optimize various aspects of IoT systems, such as energy consumption in smart grids or resource allocation in industrial IoT applications.

Machine learning acts as a teacher for computers, allowing them to learn from data and experiences. In the context of IoT and robotics, machine learning enables devices to become smarter, more efficient, and capable of adapting to their environments. From data analytics and predictive maintenance to robot control and decision-making, machine learning enhances the capabilities of IoT and robotics, making them more powerful and versatile in solving real-world challenges.

To learn more about machine learning, attend the online module Artificial Intelligence available at: https://open.ktu.edu/course/view.php?id=190

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Practical Assignments

Select and solve your challenge for a robot-based scenario by following the instructions described in the MOOC „Robotics and IoT“ (https://open.ktu.edu/course/view.php?id=196):

Choosing your Challenge. Notes on the two challenges:

https://open.ktu.edu/mod/resource/view.php?id=16963

Challenge Option 1. Designing and modeling a robot-based scenario:

https://open.ktu.edu/course/view.php?id=196&section=5

Challenge Option 2. Prototype for a IoT- and Robot-based Scenario:

https://open.ktu.edu/course/view.php?id=196&section=6

2. DIGITAL EDUCATION

Relevance: Digital education is crucial in today's technological landscape, providing unmatched access to information and learning. It crosses geographical boundaries, allowing learners to acquire knowledge and skills anytime, anywhere. By using digital tools, it enhances engagement, collaboration, and personalized learning. It also equips students with essential digital literacy skills, fostering innovation and adaptability. Additionally, digital education supports continuous professional development, lifelong learning, and makes education more inclusive and accessible to all.

The aim of the course is to develop a comprehensive understanding of digital education, covering its benefits, challenges, and applicable learning theories. Students will learn online learning strategies, pedagogical approaches, and explore various digital tools. The course also focuses on assessing and evaluating online learning programs.

Learning outcome: by the end of the course, students should have a thorough grasp of digital education and its components.

TOPIC 2.1. Introduction to Digital Education

Lesson 2.1.1. Introduction to Digital Education

Learning Outcomes

By the end of this lesson on digital education, learners will be able to:

- Articulate the concept of digital education and its alternative terms.
- Explain the significance of digital tools and technologies in enhancing teaching and learning processes.
- Differentiate between synchronous and asynchronous digital education activities and identify examples of these activities.
- Enumerate the key components of digital education and understand the role of each component in creating a comprehensive online learning experience.
- Discuss the benefits of digital education and its potential to transform education.
- Identify the challenges and considerations in implementing digital education effectively.
- **Assess institutional preparedness for digital education.**

Lesson Content

Introduction

Digital education is an approach to the use of digital tools and technologies in the process of teaching and learning (Zawacki-Richter and Jung, 2023). Digital education, also known as technology-enhanced learning, online learning or e-learning, refers to the use of digital technologies to enhance and support teaching and learning processes. It encompasses a wide range of strategies, tools, and platforms that enable educators to create interactive and engaging learning experiences for students. Digital education goes beyond traditional classroom settings by leveraging technology to facilitate anytime, anywhere learning.

VIDEO 2.1.1. Importance of Digital Education [*duration 3:24 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/84645/mod_book/chapter/2521/DE.mp4

One of the primary advantages of digital education is its ability to transcend traditional classroom boundaries, enabling anytime, anywhere learning. This flexibility allows students to access educational resources and participate in learning activities at their convenience, thus accommodating diverse learning styles and schedules. Digital education also facilitates collaborative learning environments through online forums, social media, and other digital communication tools, fostering a sense of community and peer interaction that enhances the overall learning experience.

Moreover, digital education leverages advanced technologies such as artificial intelligence, virtual reality, and augmented reality to provide immersive and adaptive learning experiences. These technologies can tailor educational content to individual learner needs, offering personalized feedback and support that can significantly improve learning outcomes. Additionally, digital education tools often include data analytics capabilities, enabling educators to monitor student progress in real-time and make data-driven decisions to enhance instructional strategies.

Furthermore, digital education promotes the development of digital literacy skills, which are essential for success in the modern workforce. By engaging with digital tools and platforms, students learn to navigate and utilize technology effectively, preparing them for future careers that increasingly rely on digital competencies.

Thus, digital education represents a transformative approach to teaching and learning, harnessing the power of technology to create flexible, interactive, and personalized educational experiences. It not only extends the reach of traditional education but also equips students with the digital skills necessary for the 21st-century landscape.

Key Points About Digital Education

The **key points about digital education** are:

- Innovative use of digital tools and technologies. It involves the innovative use of digital tools and technologies such as online platforms, educational software, multimedia resources, and social media to deliver educational content and experiences. These tools enable educators to create dynamic and interactive learning environments that go beyond traditional instructional methods.
- Comprehensive education for the digital age. The primary goal of digital education is to equip students with a well-rounded education that prepares them for success in the digital age. This includes developing digital literacy and technical skills essential for navigating in a technology-driven world.
- Personalized and flexible learning. Digital education supports personalized and flexible learning pathways, allowing students to access educational content and resources at their own pace and according to their individual learning preferences and learning style. This adaptability ensures that learners can engage with material in ways that best suit their needs.
- Diverse digital tools and approaches. Key tools and approaches in digital education include learning management systems (LMS), online course platforms, educational apps, virtual reality (VR), and big data analytics. These technologies optimize learning by providing immersive experiences, tracking progress, and offering tailored feedback.
- Effective implementation factors. Successful implementation of digital education requires addressing critical factors such as ensuring access to digital content, building the capacity of teachers and students to effectively use digital tools, and maintaining reliable internet connectivity. Overcoming these challenges is essential for maximizing the benefits of digital education.
- Transformative potential of digital education. Digital education has the potential to significantly transform the educational landscape by enhancing the quality and relevance of learning. It promotes inclusion by making education more accessible to diverse populations and improves

education administration and governance through efficient data management and communication tools.

In summary, digital education leverages digital technologies to deliver a more engaging, personalised, and effective learning experience that prepares students for success in the modern, technology-driven world by fostering essential digital skills and creating adaptable learning environments.

Defining Digital Education

In scholarly discussions, a diverse range of alternative terms has been used to designate various modes of educational delivery. These encompass expressions such as remote learning, distance learning, distance education, open learning, e-learning, flexible learning, hybrid learning, blended learning, web-based learning, online learning, mobile learning, virtual learning, technology-enhanced learning, and distributed learning as found in the extant literature (Zawacki-Richter and Jung, 2023).

Many different definitions of distance learning are available in the IGI dictionary showing that

- learning can be organized by a department or instructor using a learning management system (LMS),
- studying remotely, giving the freedom to learn at any convenient time,
- the type of learning where information and communication technology (ICT) is its main mean for content delivery, interaction and facilitation and it can be either asynchronous or synchronous.

The term Technology-Enhanced Learning (TEL) is used to describe the application of information and communication technologies to teaching and learning. Explicit statements about what the term is understood to mean are rare and it is not evident that a shared understanding has been developed in higher education of what constitutes an enhancement of the student learning experience (Kirkwood and Price, 2014).

Online teaching and learning are forms of open and distance education (Zawacki-Richter and Jung, 2023). Singh and Thurman (2019) provided multiple definitions of online learning based on the systematic literature review for over the last 30 years. The definitions included various elements such as technology, time, interactivity, and educational context. Thus, online learning is defined as learning experienced through the internet/online computers in a synchronous classroom where students interact with instructors and other students and are not dependent on their physical location for participating in this online learning experience (Singh and Thurman, 2019, p. 302).

E-learning is an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning (Sangrà et al., 2012). Even if it is not online, an interactive learning program on a tablet that is not linked to the Internet would be deemed an e-learning application.

Terms such as **blended learning** (Osguthorpe and Graham, 2003), **lexible learning** (Collis and Moonen, 2001), or **distributed learning** (Lea and Nicoll, 2002) became prevalent at the beginning of the new Millennium. The experience and practice with online learning and teaching during the Covid-19 pandemic then gave rise to other terms such as remote and hybrid learning (Zawacki-Richter and Jung, 2023).

Blended learning nowadays refers to the learning process that combines face-to-face and online interactions in such a way that both complement each other (Hrastinski, 2019). Cronje (2020) proposed that blended learning is "the appropriate use of a mix of theories, methods and technologies to optimi[s]e learning in a given context" (p. 120).

Hybrid teaching is defined as an educational approach or delivery mode that combines traditional face-to-face instruction with online learning to create a flexible and dynamic learning environment. In hybrid teaching both on-site students and remote students attend simultaneously during synchronous (real-time) teaching and learning sessions. The aim of hybrid teaching is to leverage the advantages of both traditional and digital learning methods (Vaughan et al., 2013; Beatty, 2019; Padilla Rodriguez and Armellini, 2021).

Components of Digital Education

Digital education typically comprises several key components:

- Course content. This includes the educational materials, such as interactive e- lessons, simulations, readings, videos, and assignments, that are delivered electronically through a learning management system (LMS) or other online platforms.
- Interaction. Interaction between students and instructors, as well as among students themselves, can take various forms, including collaborative learning through online discussions, forums, live chats, and video conferences.
- Assessment. Assessment methods may include quizzes, exams, essays, projects, and peer evaluations, all of which can be administered and submitted online.
- Feedback. Instructors provide feedback on student work, guiding their progress and addressing areas for improvement. This feedback can be given through written comments, recorded audio/video, or live discussions by e-tutors, e-coaching, and e-mentoring.
- Technology. Online learning relies on various technologies such as computers, the internet, learning management systems, multimedia tools, and communication platforms to facilitate the delivery of content and interaction between participants.
- Support Services. Institutions often offer online support services such as technical assistance, academic advising, counseling, and library resources to help students succeed in their online learning endeavors. Services which provide human and social dimensions can be offered to learners to support them through the online learning experience (e-tutoring, e-coaching, e-mentoring).

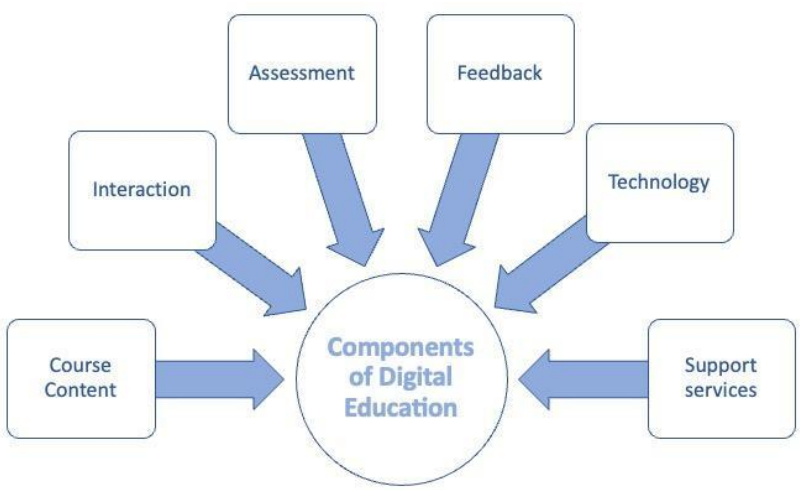

Figure 2.1.1. Components of Digital Education

Collaborative activities within online learning environments encompass a broad spectrum of interactions, spanning from engaging in discussions and exchanging knowledge to collaborating on joint projects. These activities foster a sense of community and collective learning among participants. Leveraging social software tools like chat platforms, discussion forums, and blogs, learners can seamlessly collaborate and communicate with one another irrespective of geographical barriers. These platforms facilitate dynamic interactions, enabling learners to share ideas, seek feedback, and collectively construct knowledge in a collaborative online setting. A virtual classroom is the instructional method most similar to traditional classroom training, as it is led completely by an instructor.

These components work together to create a comprehensive online learning experience that provides flexibility, interactivity, and accessibility to learners. Navigating the nuances of online learning approaches and components, students uncover the diverse methodologies employed to cultivate engaging and effective learning experiences. From the development of interactive e-lessons to the facilitation of collaborative learning environments, learners discern the intricate tapestry of elements woven into the fabric of digital education.

Synchronous **and Asynchronous Digital Education**

Digital Education activities can be synchronous or asynchronous:

1. Synchronous activities take place in real time. Synchronous communication between two people requires them to both be present at a given time. Examples of synchronous activities include chat conversations and audio / video conferencing.
2. Asynchronous activities are time-independent. A self-paced course is an example of asynchronous e-learning because online learning takes place at any time. E-mail or discussion forums are examples of asynchronous communication tools.

Synchronous activities facilitate immediate interaction and feedback, fostering a dynamic and interactive educational experience. Examples of synchronous activities include:

3. Chat conversations. These allow for instant messaging between participants, enabling quick exchanges of information and clarification of concepts.
4. Audio/Video conferencing. Platforms like Zoom, Microsoft Teams, and Google Meet enable real-time discussions, lectures, and collaborative sessions, enhancing the sense of community and immediacy among participants.
5. Live webinars. These are scheduled online seminars where participants can interact with the presenter and other attendees in real-time, often featuring Q&A sessions to address participants' questions.

Asynchronous activities, on the other hand, do not require participants to be engaged simultaneously. This flexibility allows learners to access and engage with educational materials at their own pace and on their own schedule, accommodating diverse time zones and personal commitments. Asynchronous activities support self-directed learning and reflection, enabling participants to revisit materials as needed. Examples of asynchronous activities include:

6. Self-Paced Courses. These courses provide learners with pre-recorded lectures, readings, and assignments that can be completed at any time. This model supports individualized learning trajectories and flexibility.
7. E-mail Communication. E-mail allows for the exchange of information and feedback without the need for real-time interaction, enabling thoughtful and considered responses.
8. Discussion Forums. Online forums provide a platform for ongoing discussions where participants can post questions, share insights, and engage in collaborative problem-solving at their convenience. These forums often serve as a valuable repository of information and peer support.

In conclusion, both synchronous and asynchronous digital education activities play crucial roles in creating a comprehensive and flexible learning environment. By leveraging the strengths of each modality, educators can design instructional experiences that meet the diverse needs and preferences of learners.

Preparation for Digital Education

The seamless transition to digital education hinges upon a myriad of factors, each crucial in its own right. First and foremost is the provision of essential tools for all participants, both lecturers and students alike. The acquisition and distribution of ICT equipment stand as the foundation upon which effective remote education is built. Ensuring equitable access to these tools among all involved parties is paramount, for it forms the bedrock of inclusivity within the virtual classroom.

Yet, beyond mere hardware lies the social fabric of the educational community. A conducive environment must be cultivated - one that fosters active engagement and meaningful participation. Whether through virtual forums, collaborative platforms, or tailored support systems, the social milieu must empower every individual to fully immerse themselves in the learning journey.

Central to the efficacy of digital education is the caliber of ICT resources at the institution's disposal. The adequacy and appropriateness of these technological assets determine the degree of seamlessness in organizing and conducting remote studies. From robust connectivity solutions to versatile software suites, the technological infrastructure must be not only sufficient but also conducive to the dynamic demands of virtual pedagogy.

Furthermore, the software utilized within the educational ecosystem plays a pivotal role in shaping the remote learning landscape. Its suitability and functionality are instrumental in establishing an environment conducive to remote collaboration and productivity. The seamless integration of such software into the educational framework is indispensable for facilitating effective teaching and learning experiences.

Yet, technology alone cannot guarantee success; the competencies of all participants are equally vital. Both lecturers and students must possess the requisite skills and adaptability to navigate the nuances of remote education effectively. Training initiatives and ongoing support mechanisms are essential for bridging any competency gaps and empowering individuals to thrive in the digital realm.

Lastly, the financial underpinning of the institution must not be overlooked. Adequate resources are essential for procuring ICT equipment, fostering a supportive social milieu, and facilitating professional development initiatives for educators. The institution's commitment to investing in these facets underscores its dedication to delivering quality education, irrespective of the mode of delivery.

In summation, the efficacy of digital education hinges upon a multifaceted approach - one that addresses not only technological infrastructure but also social dynamics, software capabilities, individual competencies, and financial support. It is through the harmonious orchestration of these elements that the true potential of digital education can be realized, ushering in a new era of inclusive and accessible learning.

Conclusion

In conclusion, the exploration of digital education reveals a multifaceted landscape characterised by a myriad of terms, methodologies, and components. Digital education, encompassing online learning, e-learning, and technology-enhanced learning, represents a paradigm shift in educational delivery, leveraging digital tools and technologies to create engaging and personalised learning experiences. Key points underscore the innovative use of digital tools, the cultivation of digital literacy, and the potential to transform education by enhancing quality, relevance, and inclusivity.

This Lesson delves into various modalities of digital education, from synchronous and asynchronous activities to hybrid and blended learning approaches. It emphasises the importance of comprehensive course content, interactive engagement, effective assessment, and robust support services in crafting meaningful online learning experiences. Moreover, it highlights the essential role of technology infrastructure, software integration, and individual competencies in ensuring the success of digital education initiatives.

Preparation for digital education requires a holistic approach, addressing not only technological needs but also social dynamics, pedagogical strategies, and financial support. Equitable access to resources, a supportive learning environment, and ongoing professional development are essential elements in facilitating effective digital education practices.

In essence, the efficacy of digital education hinges upon the harmonious orchestration of technological, social, pedagogical, and financial factors. By embracing a multifaceted approach that integrates these elements, institutions can unlock the true potential of digital education, ushering in a new era of inclusive and accessible learning for all.

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Lesson 2.1.2. Historical Background and Evolution of Digital Education

Learning Outcomes

By the end of this lesson, learners will be able to:

- Understand the evolution of digital education;
- Analyse the impact of the internet on education;
- Assess the role and impact of Learning Management Systems (LMS) on digital education;
- Understand the role of blogs and social media in education;
- Analyse the effectiveness, challenges, and future potential of MOOCs in education;
- Assess the impact and potential of AI and Mobile Learning (M-Learning) in increasing accessibility and personalization of education;
- Identify future trends in digital education.

Lesson Content

Introduction
The Beginnings of Digital Education
Advent of the Internet and Web
Emergence of Educational Technology
Development of Learning Management Systems
Blogs
Social Media
Massive Open Online Courses
Integration of Artificial Intelligence
Mobile Learning
Future Trends
Conclusion
Sources

Introduction

Over the last quarter-century, digital education has experienced a dramatic rise in importance, becoming a pivotal component of modern educational practices. This evolution is intricately linked with the broader concept of open education, which emphasizes accessibility, inclusivity, and the democratization of learning. Digital education serves as the overarching framework for open education, driving its principles forward through innovative technologies and methodologies.

VIDEO 2.1.2. The Evolution of Digital Education: From Chalkboards to AI [*duration 2:08 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/85080/mod_book/chapter/2529/Evolution%20of%20Digital%20Education.mp4

This Lesson 2.1.2 delves into the ascendancy of digital education, exploring its development and impact through five key educational technologies: the Internet, Learning Management Systems (LMS), blogs, social media platforms, and Massive Open Online Courses (MOOCs). Each of these technologies plays a critical role in shaping the landscape of digital education, presenting unique opportunities and challenges.

VIDEO 2.1.3. Evolution of Educational Technology 1870-202 [*duration 5:40 minutes*]**:** https://www.youtube.com/watch?v=zS-2uruw5qw&t=1s

The Beginnings of Digital Education

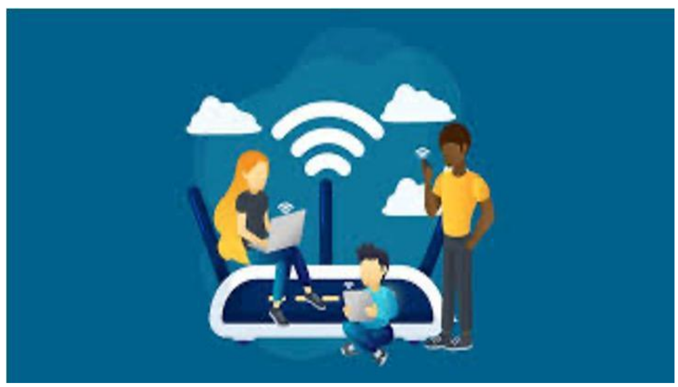
The Beginnings of Digital Education (1960s -1980s).
The origins of digital education can be traced back to the 1960s when computer-based training (CBT) systems were initially developed. These early systems utilized mainframe computers and dial-up connections to deliver educational content to learners, marking the inception of a new mode of education. Among the pioneering initiatives was the PLATO (*Programmed Logic for Automatic Teaching Operations*) system, developed at the University of Illinois. PLATO was a groundbreaking innovation that enabled students to access lessons, communicate with instructors, and participate in

online discussions, thereby establishing the interactive framework that underpins contemporary online learning.

During the 1970s and 1980s, the advent of personal computers and the gradual adoption of the internet significantly advanced the development of online learning. These technological advancements facilitated the expansion of distance education programs, which began to leverage these new tools to offer courses and degree programs to students unable to attend traditional, campus-based institutions. The University of Phoenix, founded in 1976, emerged as a notable early pioneer in this domain. By providing working adults with the opportunity to earn degrees through distance learning, the University of Phoenix set a precedent for the accessibility and flexibility that have become hallmarks of modern online education.

Advent of the Internet and Web

The inception of the World Wide Web in 1989 by Sir Tim Berners-Lee at CERN heralded a monumental shift in the educational landscape, setting the stage for a revolution in teaching and learning. This sub-section embarks on a retrospective journey, tracing the evolution of digital education through the lens of the web's inception and subsequent development.



Berners-Lee's vision emerged from the practical challenges faced by scientists at CERN, where disparate data sources hindered collaboration and information sharing. By 1990, he had conceptualised four foundational technologies - HTML, URI, HTTP, and the web browser - laying the groundwork for a globally interconnected information network.

Beyond its technical prowess, the web's design principles emphasized openness, decentralisation, and robustness, fostering an environment conducive to innovation and collaboration. Its decentralised structure posed a challenge to centralised control, empowering individuals to publish and engage in discourse without censorship.

As the web browser gained traction in the mid-1990s, its transformative potential began to materialize. Despite initial skepticism, the web's accessibility and versatility soon attracted widespread interest, transcending specialist circles. The advent of hand-crafted HTML pages hinted at the web's educational potential, facilitating communication, knowledge dissemination, and resource sharing among academics.

The emergence of Web 1.0 marked a paradigm shift in distance education, democratizing access to learning resources and reshaping the educational landscape. Institutions like the Open University embraced digital platforms, while traditional universities ventured into distance education, ushering in a new era of hybrid learning models.

The web’s profound impact reverberates across digital education, shaping the trajectory of technological innovation and pedagogical approaches. From Learning Management Systems (LMS) to Open Educational Resources (OER) and Massive Open Online Courses (MOOCs), the web remains a central protagonist in the ongoing narrative of educational transformation.

In essence, the web's legacy transcends technological innovation, symbolizing a socio-technological paradigm shift akin to the invention of the printing press. As academia grapples with the challenges and opportunities of the digital age, understanding the web's implications becomes paramount, guiding strategic responses to cultural shifts and technological advancements.

Thus, the web stands as a testament to the enduring impact of digital technologies on education, posing fundamental questions and catalyzing innovation in teaching, research, and scholarly communication. As we navigate the ever-evolving landscape of digital education, the web remains an indispensable cornerstone, shaping our understanding and redefining the boundaries of learning in the 21st century (Zawacki-Richter and Jung, 2023).

Emergence of Educational Technology

The emergence of educational technology marks a pivotal moment in the history of education, heralding a new era of innovation and possibilities. This sub-section traces the evolution of educational technology, from the introduction of early tools such as projectors, radio, and television to the initial forays into computer-based learning. Through exploring these milestones, we gain insights into the transformative power of technology in shaping teaching and learning practices.

The early 20th century witnessed the advent of revolutionary technologies that would leave an indelible mark on the field of education. Projectors, such as the magic lantern, enabled educators to enhance their presentations with visual aids, bringing lessons to life in ways previously unimaginable. Radio broadcasts soon followed, offering a means of delivering educational content to a broad audience, transcending the confines of the traditional classroom. With the introduction of television, educational programming found its way into households across the globe, offering viewers access to instructional materials and documentaries on a wide range of subjects. These early educational technologies paved the way for a more dynamic and engaging learning experience, setting the stage for further innovation in the years to come.

The dawn of the computer age ushered in a new era of possibilities for education. In the 1960s and 1970s, pioneering efforts were made to harness the power of computers for learning purposes. Early computer-based learning systems, such as PLATO (Programmed Logic for Automatic Teaching Operations), laid the foundation for interactive and personalized learning experiences. These systems allowed students to engage with educational content through computer terminals, enabling self-paced learning and immediate feedback. While rudimentary by today's standards, these early experiments paved the way for the development of more sophisticated educational software and digital learning platforms in the decades that followed.

The emergence of educational technology has transformed the landscape of education, offering new tools and methodologies to enhance teaching and learning. From the introduction of early educational technologies such as projectors, radio, and television to the initial experiments with computer-based learning, each milestone represents a step forward in the quest to harness technology for educational purposes. As we continue to embrace innovation and explore the possibilities afforded by emerging technologies, the journey of educational technology unfolds, shaping the future of learning in profound and unprecedented ways.

Development of Learning Management Systems

At the forefront of digital education stands the Learning Management System (LMS) or Virtual Learning Environment (VLE), a cornerstone technology with far-reaching implications, both beneficial and challenging. Emerging as a comprehensive solution for e-learning in universities, the LMS swiftly became a central pillar despite recurring predictions of its obsolescence.

Before the advent of the LMS, e-learning tools were fragmented, relying on a patchwork of platforms such as bulletin boards, content management systems, and bespoke web pages. This diversity posed reliability issues and varied across departments within universities. The emergence of early systems like Virtual-U and FirstClass in the 1990s hinted at a shift toward integrated solutions.

As e-learning gained prominence in university settings, the need for a standardized, enterprise-level platform became apparent. The LMS consolidated popular tools into a single solution, streamlining implementation and support across institutions. Yet, its adoption often led to long-term commitments to vendors, raising concerns about institutional autonomy.

Throughout the 2000s, LMS adoption surged, with nearly all higher education institutions deploying them by 2005. However, initial utilization often mirrored traditional classroom models, focusing on content delivery rather than innovative pedagogies. Even during the COVID-19 pandemic, universities predominantly relied on LMS for online lectures via platforms like Zoom, highlighting persistent usage patterns.

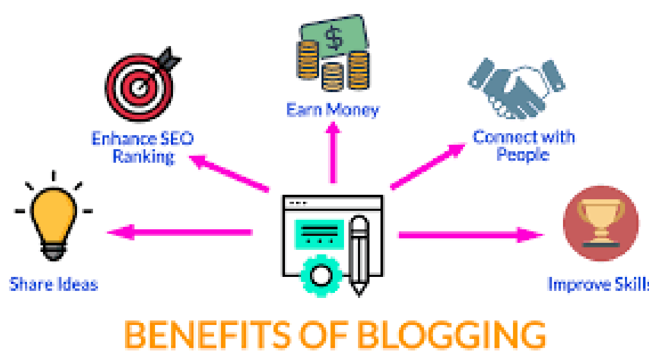
Despite its widespread use, the LMS requires substantial investments in terms of finances, expertise, and institutional resources. Over time, institutions developed administrative structures and processes closely tied to the LMS, fostering a culture of "tool-focused solutionism" that may stifle pedagogical innovation.

Despite premature predictions of its demise, the LMS continues to evolve, incorporating features like integrated social media tools and e-portfolios. Its robustness offers institutions valuable insights into learning patterns and behaviors, driving ongoing developments in digital education.

While the LMS has facilitated the rapid development and standardization of e-learning, it has also prompted debates about its impact on innovation and openness in education. Balancing stability with the need for experimentation remains a challenge, yet the LMS persists as a foundational element in the digital education landscape.

In essence, the LMS has been instrumental in expanding digital education, providing stable platforms for diverse educational endeavors. However, its dominance has sometimes come at the expense of fostering innovation and openness, prompting ongoing reflections on its role in shaping the future of education (Weller, 2023; Zawacki-Richter and Jung, 2023).

Blogs



Blogging emerged alongside educational advancements, becoming a cornerstone of educational technology. Its inception mirrored the rise of Web 2.0, intertwining with broader internet developments. As an extension of the web, blogging democratized publishing, enabling individuals to share diaries, journals, and resources easily. Syndication technologies, notably RSS, empowered readers to subscribe to blogs, revolutionizing content distribution.

In the early 2000s, educators recognized blogging's potential for teaching and learning. Educational bloggers formed a vibrant community, leveraging blogs to expand academic discourse beyond formal institutions. Blogs provided a platform for free expression, offering a new avenue for scholarly identity formation.

Blogs reshaped academic identity, complementing traditional markers of scholarly achievement. However, tensions arose as institutions favored conventional publication methods over innovative digital communication. Academics navigated dual roles, balancing online engagement with institutional expectations. Despite challenges, blogs offered visibility and networking opportunities, particularly for early-career scholars.

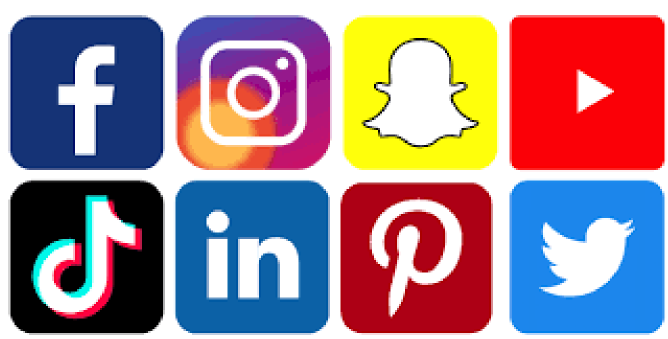
The concept of Networked Participatory Scholarship (NPS) emerged, reflecting scholars' use of social networks to advance their research agendas. NPS facilitated collaboration, critique, and dissemination of scholarly work. However, concerns emerged regarding online harassment and disparities in online prestige.

Amid growing concerns about data privacy, educators advocated for "owning your own domain" and hosting blogs independently. This shift aimed to reclaim control over digital identities and data ownership, countering the dominance of third-party platforms.

Blogs transcended their initial role as educator tools, gaining traction among students. Imagining an alternate history, where institutions embraced blogging platforms as Learning Management Systems (LMS), underscores differing visions of digital education. While blogs offer openness akin to the early web, LMSes represent centralized control, sparking philosophical debates about the nature of online learning.

Blogs epitomise the intersection of technology and education, embodying tensions between openness and control in digital learning environments. Their evolution reflects broader shifts in academic culture and online engagement. As educators navigate these complexities, blogs remain a symbol of autonomy and collaboration in the digital age (Weller, 2023; Zawacki-Richter and Jung, 2023).

Social Media

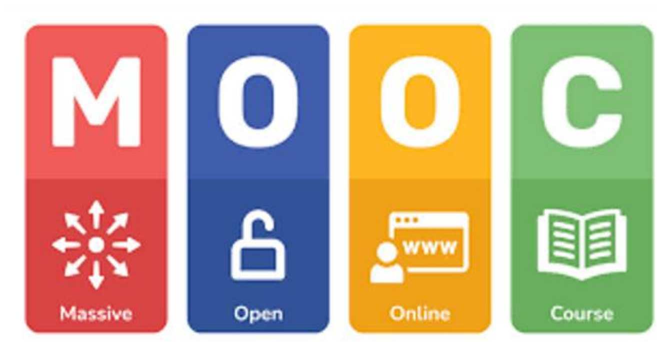


Social media, a third-party technology in education alongside dominant tools like Learning Management Systems (LMS), embodies both positive and negative aspects. While it fosters connection and engagement, it also spreads disinformation. Initially democratizing, it reshaped academic relationships and student engagement. Yet, educators face a quandary: balancing its benefits against its harms, with some opting out altogether.

Potential benefits include increased student recruitment, engagement, and retention. However, navigating fake news and misinformation is crucial, requiring expertise development. Notably, social media platforms often serve as infrastructure for online experiences, blurring distinctions between professional and personal spheres. This blurring, while beneficial for reaching diverse audiences, also poses risks like context collapse, where different audiences encounter the same content, leading to misunderstandings or harassment.

Ultimately, social media offers tools and opportunities for education but demands critical navigation due to its complex nature and inherent risks (Weller, 2023; Zawacki-Richter and Jung, 2023).

Massive Open Online Courses



A Massive Open Online Course (MOOC) is a model for delivering learning content online to any person who wants to take a course, with no limit on attendance. MOOCs surged in popularity in 2012, dubbed "the year of the MOOC" by The New York Times. They combine elements of open education, video content, and Web 2.0 hype. Initially championed by educators like George Siemens and Stephen Downes, MOOCs gained widespread attention when Stanford professor Sebastian Thrun's course on artificial intelligence attracted over 100,000 learners.

Despite early excitement, MOOCs have not revolutionized education as predicted. Completion rates are low, demographics skewed toward already educated individuals, and sustainability remains a challenge due to high costs. This led to a shift in focus, with some institutions integrating MOOCs into traditional learning environments.

Practically, millions have found MOOCs beneficial, with applications ranging from personal enrichment to formal education. They've also bolstered the profile of online education and open practices, even though they may not fully embody openness themselves.

In conclusion, while MOOCs have brought digital and open education closer, they fall short of some ideals, often veering toward conventional education models driven by commercial interests (Weller, 2023; Zawacki-Richter and Jung, 2023).

Integration of Artificial Intelligence

In recent years, the integration of Artificial Intelligence (AI) in education has transformed the traditional learning landscape, offering personalised and adaptive learning experiences. This sub-section explores AI's pivotal role in fostering personalised learning, its utilisation in adaptive learning systems, and the ethical considerations surrounding its implementation.

AI's Role in Personalised Learning

Customized learning paths. AI algorithms analyse learners' behaviors, preferences, and performance data to tailor learning paths suited to individual needs. This enables students to learn at their own pace and style, addressing their unique strengths and weaknesses.

Targeted content delivery. AI-powered systems deliver content in various formats (text, audio, video) based on learners' preferences and comprehension levels, ensuring optimal engagement and understanding.

Adaptive feedback and assessment. AI provides timely and personalised feedback to learners, highlighting areas for improvement and offering targeted interventions to enhance learning outcomes.

Use of AI in Adaptive Learning Systems

Dynamic content recommendations. Adaptive learning platforms leverage AI algorithms to recommend content and learning activities based on learners' progress, interests, and learning history.

Real-time performance monitoring. AI continuously monitors learners' performance and adjusts learning materials and challenges accordingly, fostering a dynamic and responsive learning environment.

Personalised intervention strategies. AI identifies students at risk of falling behind or those in need of additional support, enabling educators to provide timely interventions and support mechanisms.

Ethical Considerations

Data privacy and security. AI systems collect and analyze vast amounts of student data, raising concerns about privacy, data security, and potential misuse of sensitive information.

Bias and fairness. AI algorithms may inadvertently perpetuate biases present in training data, leading to unequal treatment or opportunities for certain groups of students. Ethical AI design and rigorous evaluation are essential to mitigate bias and ensure fairness.

Transparency and accountability. AI-driven decision-making processes in education should be transparent, understandable, and accountable. Educators and policymakers must ensure transparency in AI algorithms' functioning and decision-making criteria.

Equity and access. The deployment of AI in education should not exacerbate existing inequalities. Efforts should be made to ensure equitable access to AI-driven educational resources and opportunities for all learners, regardless of socio-economic background or geographic location.

The integration of AI in education holds immense potential to revolutionise learning experiences in digital education, offering personalized and adaptive pathways to knowledge acquisition. However, ethical considerations must guide the development and implementation of AI systems in education, ensuring fairness, transparency, and equity for all learners. By harnessing the power of AI responsibly, educators can empower students to thrive in the rapidly evolving digital age.

Mobile Learning

In the ever-evolving landscape of education, a silent revolution is taking place, one that transcends the confines of traditional classrooms and textbooks. It's the rise of Mobile Learning (M-Learning), a journey fueled by the exponential growth of mobile devices, and the unwavering quest for accessibility and empowerment in education.

As smartphones and tablets become ubiquitous companions in our daily lives, their presence in educational institutions has become more pronounced than ever before. With Bring Your Own Device (BYOD) initiatives gaining traction, students are empowered to wield the power of their personal mobile devices as tools for learning, breaking down barriers and opening doors to a world of knowledge at their fingertips.

But the impact goes beyond mere convenience. M-Learning represents a paradigm shift, a seismic transformation in the way we approach education. No longer confined to the four walls of a classroom, learning becomes a fluid, dynamic experience, accessible anytime, anywhere. Whether it's a bustling city street or a remote village, the promise of education is no longer out of reach.

At the heart of M-Learning lies its unparalleled ability to foster inclusivity. With customizable interfaces, multimedia content, and assistive technologies, learners of all backgrounds and abilities find themselves welcomed into the fold of education. Disabilities and learning difficulties are no longer insurmountable obstacles but challenges to be overcome with the aid of technology.

But perhaps the most profound impact of M-Learning lies in its capacity for personalization. Through adaptive algorithms and data analytics, learning experiences are tailored to suit the unique needs and preferences of each individual learner. From personalised learning pathways to real-time feedback, education becomes a journey of self-discovery, empowering learners to chart their own course to success.

As the narrative of M-Learning unfolds, it is exemplified by a myriad of innovative applications that have reshaped the educational landscape. From TED Talks inspiring minds to Kahoot! gamifying learning, from Khan Academy providing access to knowledge to Quizizz making learning interactive, and from Coursera offering world-class courses to Quizlet facilitating collaborative study sessions, the possibilities are endless.

In the grand tapestry of education, Mobile Learning emerges as a thread that weaves together accessibility, empowerment, and inclusivity. It is a journey fueled by the relentless march of technology and the unyielding belief in the transformative power of education. As we embrace the dawn of a new era in learning, let us embark on this journey together, armed with the tools of innovation and the spirit of discovery, to unlock the boundless potential that lies within each and every learner.

Future Trends

As we stand on the precipice of a new era in education, propelled by rapid advancements in technology and evolving pedagogical approaches, it is imperative to gaze into the crystal ball and envision the future of digital education. However, amidst the uncertainty, one certainty remains: the importance of continuous adaptation to navigate the ever-changing landscape of education in the digital age.

Predictions for the Future of Digital Education

Augmented Reality (AR) and Virtual Reality (VR) integration. With the growing sophistication of AR and VR technologies, we can anticipate their widespread integration into educational settings. From immersive virtual field trips to interactive anatomy lessons, AR and VR hold the potential to revolutionize experiential learning experiences.

Artificial Intelligence (AI) personalisation. AI-driven adaptive learning systems will become more sophisticated, offering hyper-personalized learning experiences tailored to individual learners' needs, preferences, and learning styles. AI will not only assist in content delivery but also in student assessment and intervention strategies.

Gamification and game-based learning. Gamification principles and game-based learning approaches will continue to gain traction, engaging learners through interactive and immersive experiences. Educational games will evolve to encompass diverse subjects and disciplines, catering to learners of all ages and levels.

Collaborative online learning communities. Online learning communities and social learning platforms will flourish, facilitating collaborative learning experiences, knowledge sharing, and peer-to-peer support. Learners will connect across geographical boundaries, fostering a global learning ecosystem.

Lifelong learning and microlearning. The concept of lifelong learning will become increasingly prevalent, with individuals engaging in continuous skill development and knowledge acquisition throughout their lives. Microlearning, characterised by bite-sized learning modules and on-demand access to resources, will cater to the needs of busy learners seeking flexible learning opportunities.

Importance of Continuous Adaptation

Technological advancements. The rapid pace of technological innovation necessitates continuous adaptation to harness the latest tools and platforms for educational purposes. Educators must stay abreast of emerging technologies and their potential applications in teaching and learning.

Pedagogical innovation. As educational paradigms evolve, educators must embrace pedagogical innovation to meet the diverse needs and preferences of learners. This may involve adopting learner-centered approaches, integrating project-based learning methodologies, or fostering creativity and critical thinking skills.

Changing learner demographics. The demographics of learners are evolving, with an increasing number of adult learners, non-traditional students, and learners from diverse cultural backgrounds entering educational spaces. Educators must adapt their instructional strategies to accommodate the unique characteristics and learning styles of these learners.

Globalization and cultural awareness. In an interconnected world, educators must cultivate cultural awareness and sensitivity to cater to the needs of learners from diverse cultural and linguistic backgrounds. Adapting curriculum content, instructional materials, and assessment methods to reflect cultural diversity fosters inclusivity and promotes cross-cultural understanding.

Continuous improvement. Continuous adaptation is not only about keeping pace with change but also about fostering a culture of continuous improvement. Educators should embrace reflective practice, seek feedback from learners, colleagues, and stakeholders, and engage in professional development activities to enhance their teaching effectiveness and student outcomes.

Conclusion

In conclusion, the future of digital education holds immense promise, characterized by technological innovation, pedagogical evolution, and a commitment to lifelong learning. However, realizing this vision requires a steadfast commitment to continuous adaptation, as educators navigate the complex and dynamic landscape of education in the digital age. By embracing change, fostering innovation, and prioritizing the needs of learners, we can collectively shape a future where education is accessible, engaging, and transformative for all.

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Lesson 2.1.3. Benefits and Challenges of Digital Education

Learning Outcomes

By the end of this lesson, learners will be able to:

- Identify key benefits and articulate the primary advantages of digital education;
- Analyse how digital education leverages technology to enhance learning experiences and break down traditional educational barriers;
- Critically assess the major challenges associated with digital education.

Lesson Content

Introduction

Benefits of Digital Education.

Challenges of Digital Education

Conclusion

Sources

Introduction

In an era defined by rapid technological advancement and global connectivity, digital education has emerged as a transformative force in the realm of learning and knowledge dissemination. By harnessing the power of digital technologies, education is no longer confined to traditional classroom settings but has transcended physical boundaries, offering a myriad of benefits to learners worldwide. From enhanced accessibility to personalised learning experiences, digital education has revolutionized the way we acquire knowledge, making it more accessible, flexible, and engaging than ever before.

This Lesson delves into the multifaceted advantages of digital education, elucidating its key benefits that have reshaped the educational landscape. From breaking down geographical barriers to fostering global collaboration, digital education has democratised access to quality learning opportunities, empowering individuals from diverse backgrounds to pursue their educational aspirations. Moreover, it explores the challenges that accompany the digital revolution in education, ranging from technological barriers to concerns surrounding privacy and security.

As we navigate the complexities of digital education, it becomes imperative to not only celebrate its successes but also address the obstacles that hinder its full potential. By understanding both the opportunities and challenges inherent in digital education, we can chart a course towards a future where education is not only accessible to all but also tailored to meet the diverse needs of learners in an increasingly interconnected world.

VIDEO 2.1.4. Online Education: Advantages vs Disadvantages [*duration 1:02 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/85083/mod_book/chapter/2544/Benefits%20and%20Challenges.mp4

Benefits of Digital Education

The main benefits of digital education are:

- Accessibility
- Flexibility
- Engagement
- Cost-effectiveness
- Global collaboration

Accessibility. Digital education breaks down physical barriers to learning. It allows individuals to access educational resources and materials from anywhere with an internet connection, regardless of geographical location or physical limitations. This accessibility is particularly advantageous for people in remote areas, those with disabilities, or individuals who cannot attend traditional classrooms due to work or family commitments.

Flexibility. Digital education offers flexibility in terms of scheduling and pacing. Learners can access course materials at any time that suits them, allowing them to study around their existing commitments. Additionally, digital platforms often offer self-paced learning options, allowing students to progress through courses at their own speed, accommodating different learning styles and preferences.

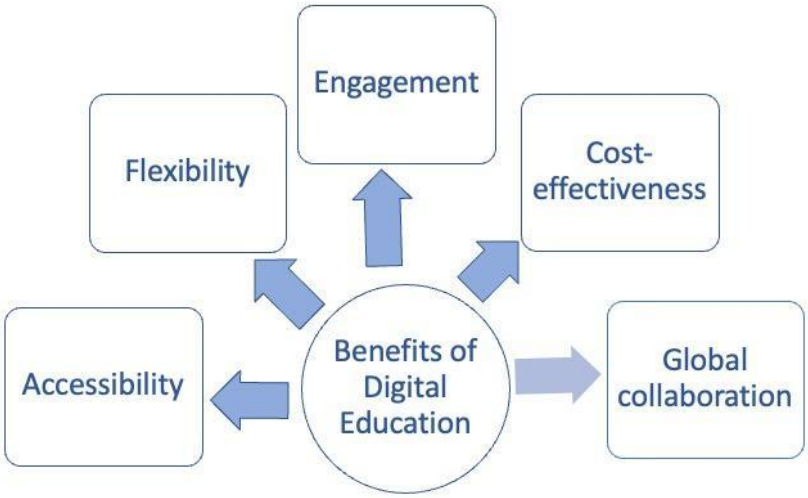

Figure 2.1.2. Benefits of Digital Education

Engagement. Digital education leverages various interactive tools and multimedia resources to engage learners in ways that traditional methods often cannot. Through videos, simulations, interactive quizzes, and online discussions, students can actively participate in their learning process, leading to deeper understanding and retention of knowledge. Furthermore, digital platforms can adapt content to individual learning needs, providing personalised learning experiences that keep students engaged and motivated.

Cost-effectiveness. Digital education can be more cost-effective than traditional forms of education. It eliminates the need for expenses associated with physical infrastructure, such as classrooms and textbooks. Additionally, it reduces travel costs for both students and instructors. Moreover, digital materials can often be distributed at a lower cost compared to printed materials, making education more affordable and accessible to a wider range of learners.

Global collaboration. Digital education fosters collaboration among students and educators from around the world. Through online forums, video conferencing, and collaborative tools, learners can connect with peers and experts regardless of their location. This global collaboration exposes students to diverse perspectives and experiences, enriching their learning journey and preparing them for an increasingly interconnected world. Furthermore, digital platforms enable international partnerships between educational institutions, allowing for the exchange of knowledge, resources, and best practices on a global scale.

Overall, digital education offers numerous benefits that enhance accessibility, flexibility, engagement, cost-effectiveness, and global collaboration, ultimately democratising access to quality education and empowering learners to succeed in the digital age.

Challenges of Digital Education

Challenges associated with digital education are:

- Technological barriers
- Quality assurance
- Social isolation
- Digital literacy
- Privacy and security

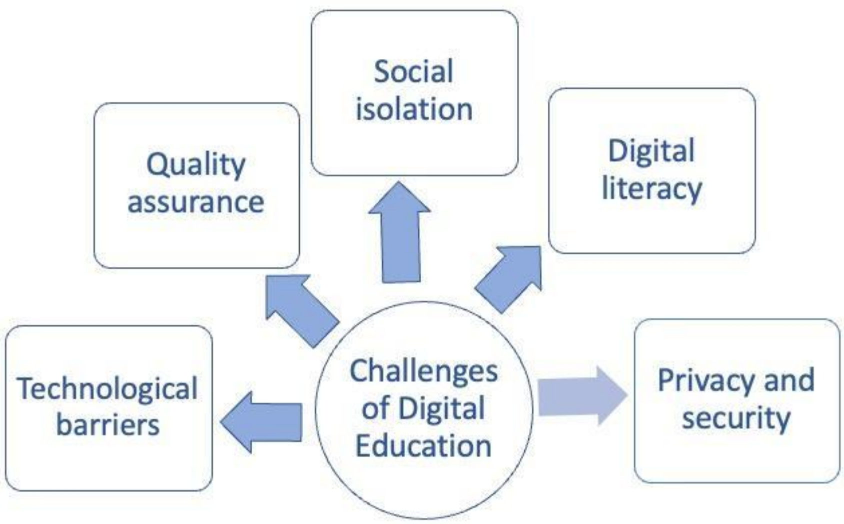

Figure 2.1.3. Challenges of Distance Education

Technological barriers. Not everyone has equal access to technology or reliable internet connections, creating a digital divide. This disparity in access can hinder some students' ability to fully participate in digital education programs. Additionally, technological glitches or issues with devices, software, or connectivity can disrupt learning experiences, causing frustration and impacting the quality of education delivered.

Quality assurance. Ensuring the quality of digital education programs can be challenging. The absence of face-to-face interaction between students and instructors may lead to difficulties in assessing learning outcomes and providing timely feedback. Moreover, the proliferation of online courses from various providers makes it difficult for students to discern the quality and credibility of educational content and credentials.

Social isolation. Digital education can contribute to feelings of social isolation among students. The lack of physical interaction with peers and instructors may lead to a sense of disconnection and loneliness, impacting students' motivation and mental well-being. Additionally, the absence of social cues and non-verbal communication in online interactions can make it challenging to build relationships and foster a sense of community within digital learning environments.

Digital literacy. Digital education requires a certain level of digital literacy, which not all students possess. Some learners may struggle to navigate online platforms, use digital tools effectively, or critically evaluate online information. This lack of digital literacy can impede students' ability to fully engage with digital learning resources and participate meaningfully in online discussions and activities.

Privacy and security. Digital education raises concerns about the privacy and security of students' personal data and online interactions. Educational institutions and online platforms must implement robust security measures to protect sensitive information from unauthorized access, data breaches, and cyberattacks. Additionally, ensuring students' privacy rights while using online learning platforms and tools requires careful consideration of data collection, storage, and usage practices.

Addressing these challenges requires a comprehensive approach that involves investment in infrastructure and technology, development of digital literacy skills, implementation of quality assurance mechanisms, promotion of social interaction and community-building strategies, and prioritization of privacy and security measures. By proactively addressing these challenges, digital education can fulfill its potential to provide accessible, high-quality learning experiences for all students.

Conclusion

In conclusion, the exploration of the benefits and challenges of digital education illuminates its profound impact on modern learning. Digital education transcends geographical limitations, offering unparalleled accessibility and flexibility to learners worldwide. Its engagement tools and personalized approaches foster deep understanding and retention of knowledge, while its cost-effectiveness and global collaboration opportunities democratize education on a global scale.

However, amidst its transformative potential, digital education presents challenges that must be addressed. The digital divide, quality assurance concerns, social isolation, digital literacy gaps, and privacy/security risks underscore the need for a holistic approach to implementation. Investment in infrastructure, cultivation of digital literacy skills, assurance of quality standards, promotion of social interaction, and safeguarding privacy are pivotal in realizing the full benefits of digital education.

By navigating these challenges with diligence and foresight, digital education can evolve into a dynamic force for equitable, accessible, and enriching learning experiences, shaping a future where education knows no boundaries and empowers learners of all backgrounds to thrive in an interconnected world.

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Self-Assessment Quiz

Test your knowledge by taking the **Self-Assessment Quiz** (https://open.ktu.edu/mod/quiz/view.php?id=17184) included in the 1st Topic, "Introduction to Digital Education" of the MOOC "Digital Education" (https://open.ktu.edu/course/view.php?id=194).

TOPIC 2.2. Learning Theories and Digital Education

Lesson 2.2.1. Behaviorism, cognitivism, and constructivism in digital education

Learning Outcomes

By the end of this lesson, learners will be able to:

- Describe the key principles of behaviourism, cognitivism, constructivism, and connectivism;
- Compare and contrast different learning theories;
- Evaluate how each theory can be implemented in online teaching environments.

Lesson Content

Introduction

Behaviourism

Cognitivism

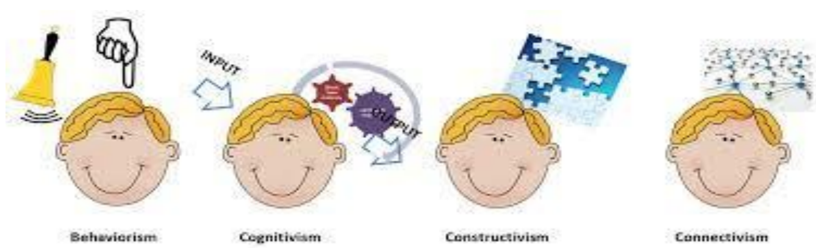
Constructivism

Connectivism

Conclusions

Sources

Introduction



There are many theories associated with education. Learning theories describe the nature of learning, providing multiple perspectives on when, how, and why various types of learning happen. Instructional-design theories provide guidelines in the practices that can facilitate learning based on scientific learning principles implied by learning theories.

When referring to digital education and its advantages to learners, four theories can help us to understand how to go about teaching online:

- behaviourism,

- cognitivism,
- constructivism and
- connectivism.

“Learning and developmental theories are useful for understanding why an instructional-design theory works, and, in areas where no instructional-design exists, they can help an educator to invent new methods or select known instructional methods that might work”. (Reigeluth, 1999, p.13).

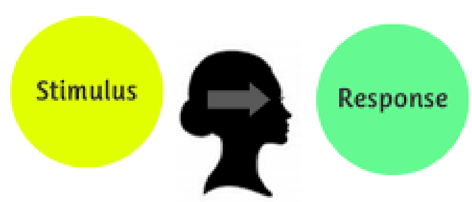
VIDEO 2.2.1. Unlocking Digital Education: 4 Key Learning Theories [*duration 1:48 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88864/mod_book/chapter/2643/Learning%20Theories.mp4

It can be useful to bear in mind the general ideas behind them when considering moving into the online teaching environment (OU, 2017).

VIDEO 2.2.2. The 5 Learning Theories [*duration 9:02 minutes*]: https://www.youtube.com/watch?v=sAxAegfVd00&t=2s

Behaviourism

Burrhus Frederic Skinner (1968) and **Edward Lee Thorndike** (1928) were the main proponents of behaviourism. They examined how behaviour is linked to experience and reward.



Knowledge and skills are defined by behaviourism as observable and quantifiable behaviours. Learning is the act of forming connections between an external stimulus, an external response, and an external consequence (i.e., reinforcement or punishment) in order to accumulate information (behaviours or performances).

For instance, if students answer correctly on their vocabulary quiz (an external stimulus) and receive 100% of the possible score, they receive a tiny reward (reinforcement). Recalling facts and automatically carrying out a particular task are two examples of behaviours that can be explained by behaviourism. These behaviours can be reduced to a small number of perceptual or motor skills (Nathan and Sawyer, 2022; Ertmer & Newby, 2013).

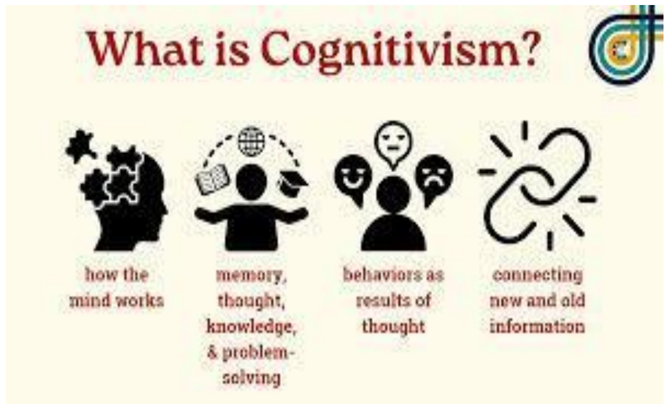
VIDEO 2.2.3. Behaviourism by Monaghan et al. (2012) [*duration 4:32 minutes*]: https://www.youtube.com/watch?v=RU0zEGWp56Y

The fundamental ideas of behaviourism are still widely applied in instructional design because they can successfully elicit the intended response in response to a stimulus. One kind of game-based learning that is built on incentives and repetition is one example. The fundamental component influencing whether learning (forming stimulus-response associations) is formed, developed, and sustained is the environment - that is, the arrangement of stimuli and consequences that could elicit the desired response (Ertmer and Newby, 2013).

- Among the behaviourist approaches to instructional design are:
- Task analysis to determine the behavioral objectives, instructional sequence (progressing from simple to more complex levels of performance), and instructional cues (i.e., external stimulus and consequences);
- Design of instructional cues and reinforcements for eliciting desired responses and strengthening correct responses with corrective feedback;
- Learner analysis with pre-assessment to determine learners' performance on prerequisite learning;
- Design of practice situation that prompts the association of stimuli and response in diverse performance settings;
- Design of assessment that examines learners' reproductive rate of desired responses.

Nevertheless, behaviourism is limited in its ability to explain non-conditioned learning. Because behaviourism has its limitations, instructional designers should recognise this when higher-level learning outcomes are needed and emphasise that students are active agents of their own learning rather than passive recipients of conditioning. Other viewpoints provide a better explanation for this higher-level learning.

Cognitivism



Cognitivism largely replaced behaviourism and came to prominence in the late 20th century. This theory concentrated on the organisation of knowledge, information processing and decision-making. David Ausubel (1960) and Jerome Bruner (1966) were the main proponents of cognitivism. Bruner pursued the notion that learners should be given opportunities to discover for themselves relationships that are inherent in the learning material, a teaching technique he named **'scaffolding'.**

According to cognitivism, knowledge is the mental schema that students use to map the outside world. Knowledge is kept in long-term memory and can be retrieved to process external information in working memory. Declarative, procedural, and conditional knowledge are some of the fundamental building blocks of knowledge that can be broken down and simplified. Learning is the process of applying different cognitive and metacognitive strategies to encode, organise, analyse, and structure external information in order to create a new schema or modify an existing schema that is retained in memory. The boundaries for recognising the similarities and differences of different information during learning processes and the transfer of learning processes were created by the past knowledge of the learners.

VIDEO 2.2.4. Cognitivism [*duration 3:44 minutes*]:
https://www.youtube.com/watch?v=gugvpoU2Ewo

Compared to behiorism, the mental processes and structures - perception, thinking, language, and reasoning - are more suited to describe complex kinds of learning since they are fundamental to people's attention, memory, and idea development. Learning organised complex knowledge that can be broken down, standardised, and analysed into an algorithmic or rule-based system is best explained by cognitivism. For instance, to learn programming, a learner could gradually become proficient in each of the sub-tasks (such as understanding syntax, mastering loops and conditionals, implementing functions, and so forth) and then put all of the sub-tasks together to complete a complex program or application.

The goal of cognivist instruction is to transfer knowledge as effectively and efficiently as feasible through processing processes. The main elements that account for learning include structured instructional components, learners' prior knowledge and learning techniques to approach learning and prevent forgetting, and learning motivation. Among the cognitivist approaches to instructional design are:

- Task/knowledge analysis to identify and illustrate the prerequisite relationships which results in hierarchical structures of knowledge which results in hierarchical structures of learning content and decomposition of instruction;
- Learner analysis to determine learners’ predisposition to learning (i.e., how do learners activate, maintain, and direct their learning) and to bridge between learners’ prior knowledge and the target learning;
- Design of information bridge to facilitate recall of prerequisite skill and draw analogies between prior knowledge and target knowledge;
- Information elaboration and chunking that structure, organize, and sequence information to facilitate optimal processing;
- Design of practice and assessment to provide informative feedback that directs student’s information processing, self-regulated learning, and knowledge transfer;
- Design of learning environment that actively involves learners in the learning process and supports learners’ self-regulated learning and motivation maintenance.

Educational designers should be mindful of the limitations of cognitivism when examining the learner-centered approach to complex learning (i.e., learning and the meaning of knowledge vary across contexts and cases). They should also stress that each learner is a unique constructive learning agent rather than a computer-like information processor.

In an online teaching environment, this could manifest itself in the teacher providing regular and focused support to each learner in the early stages of the course, but making less frequent supporting interventions as the learner begins to act successfully by themselves. Ausubel’s work in this area would suggest that it is better for the teacher to provide some materials in advance, that allow the learner to ‘organise’ their learning approach prior to them accessing the actual course materials, so that they have already developed much of the skillset they will need to successfully undertake the course (OU, 2017).

Constructivism

Constructivism is concerned with how knowledge is constructed. The main proponents of constructivism were Jean Piaget (1957) and Lev Vygotsky (1986). Piaget was interested in how knowledge is constructed by the individual. Vygotsky was more concerned with how the social construction of knowledge has an important role to play in this process. With respect to online teaching, one of the important notions to take from Vygotsky's work is the **'zone of proximal development'**.

Constructivism contests the idea that the human mind is capable of mapping an absolute, objective external world one-to-one. Every learner's personal meanings are derived from actual real-world experiences, and knowledge is always generated in context (Ertmer and Newby, 2013). Constructivism, as opposed to behaviourism and cognitivism, is a paradigm shift that emphasises how learners construct their knowledge via experience, reflection, and meaning-making.

Learning is a process in which students creatively and situationally interpret real events using existing information from a variety of sources to produce new and meaningful "schema" (Nathan and Sawyer, 2022). As suggested by behaviourism and cognitivism, learning is the outcome of active interactions with the outside world that include reflection, adaptation, and modification rather than the transfer of an intact knowledge structure from the outside world into memory (Ertmer and Newby, 2013). As a result, learners' schema is always subject to modification in light of their evolving and present understanding of the outside world.

VIDEO 2.2.5. Constructivism [*duration 4:22 minutes*]:
https://www.youtube.com/watch?v=Xa59prZC5gA&t=2s

Constructivism is typically categorized based on how learners interact with the external environment to create meaning and construct knowledge:

- Cognitive constructivism. By seeking equilibrium in the cognitive conflict, knowledge is created during the assimilation and accommodation processes. Through experimental procedures and active reflection, like inquiry-based learning, the cognitive conflict is overcome. Learning is an individual process in which ideas come before words in order to make sense of what has been experienced in the real world and to integrate new information into existing knowledge. Learners' ability to make sense of new events and concepts is limited by their prior knowledge and cognitive capacity.

Assimilation refers to the process of brining in new knowledge to the existing schemas.

Accommodation refers to the process of modifying the existing schemas to accommodate the new information or knowledge.

Cognitive conflict refers to the differences between encountered experiences and presented information.

- Social constructivism: Language use, meaning negotiation, and active reflection all play a role in the mediation of knowledge formation through social interaction. Thinking and language, especially inner speech, are essential components of learning and have an impact on the process of learning. More experienced people can scaffold learners' learning in the Zone of Proximal Development (ZDP) throughout social contact and culturally structured activities to help learners obtain cognitive progress that they could not attain on their own.

Zone of Proximal Development (ZDP) is a zone where learning could occur with learners' individual efforts and the assistance of more knowledgeable others.

Connectivism

Connectivism is a contemporary learning theory that posits effective learning requires the integration of diverse thoughts, theories, and information, facilitated by modern technology. It emphasizes the critical role of digital tools in contemporary education, acknowledging the boundless opportunities for learning afforded by our interconnected era. A fundamental aspect of connectivism is the encouragement of group dynamics. Collaboration and open dialogue among learners enable the sharing of diverse perspectives, thereby enhancing decision-making, problem-solving, and the understanding of complex concepts (Kurt, 2023).

Moreover, connectivism advocates for decentralized learning, asserting that education is not confined to the individual but extends to platforms such as social media, online communities, and extensive informational databases.

The origins of connectivism can be traced to the work of academics **George Siemens** and **Stephen Downes** in 2005. Their seminal publications illuminated the profound impact of technology on education. They argued that the digital revolution has not only increased information accessibility but also accelerated the speed at which it is disseminated.

While both Siemens and Downes remain strong proponents of connectivism, their focus areas slightly diverge. Siemens has largely concentrated on exploring the social dimensions and interactions underpinning the theory. On the other hand, Downes has delved deeper into the realm of artificial intelligence, considering how both non-human entities and machine-based tools can facilitate learning.

VIDEO 2.2.6. Connectivism by George Siemens [*duration 3:14 minutes*]: https://www.youtube.com/watch?v=yx5VHpaW8sQ&t=1s

This theory takes into account the availability of a plethora of information on the web, which can be shared around the world almost instantaneously with the rise of social networking. Connectivism draws on chaos theory's recognition of 'everything being connected to everything else'. It also draws on networking principles, and theories of complexity and self-organisation, and is built on a notion that 'the connections that enable us to learn more are more important than our current state of knowing' (Siemens, 2005).

Unlike the other theories presented before, connectivism is 'a learning theory for the digital age' (Siemens, 2005). It is also newer and less established in terms of a body of research. Whether or not you agree with its arguments, two very important questions for this course are prompted by connectivism: has the internet fundamentally changed what learning is? (OU, 2017).

Conclusions

In the realm of educational psychology, understanding how individuals learn is paramount. Various learning theories have emerged over time, each offering unique insights into the mechanisms behind learning.

Behaviourism posits that learning is fundamentally a change in behavior elicited by external stimuli. This theory emphasizes observable and measurable behaviors, focusing on how individuals respond to different stimuli through processes like reinforcement and punishment. Classical and operant conditioning are central to this perspective, illustrating how associations between stimuli and responses can shape behavior over time.

In contrast, cognitivism delves into the internal processes that underpin learning. Influential theorists like Jean Piaget and Jerome Bruner have highlighted the significance of mental processes such as thinking, memory, and problem-solving. According to cognitivism, learning involves the acquisition and organization of knowledge. The theory underscores the importance of schemas, which are mental structures that help individuals categorize and store information. This perspective shifts the focus from external behaviors to the cognitive processes occurring within the learner's mind.

Constructivism, with key contributions from Lev Vygotsky and Jean Piaget, views learning as an active, constructive process. This theory posits that learners actively build new knowledge on the foundation of their previous experiences. Constructivism emphasizes the role of social interaction and cultural context, suggesting that learning is deeply embedded in social environments. Concepts such as the Zone of Proximal Development (ZPD) and scaffolding are crucial, highlighting how learners progress through guided interaction and support.

Connectionism, presents learning as the formation of connections or associations between stimuli and responses. This theory has a strong focus on the neural underpinnings of learning, suggesting that the brain’s neural networks adapt based on experience. Modern interpretations of connectionism incorporate neural network models and the concept of synaptic plasticity, explaining learning at a biological level.

Each of these theories - behaviourism, cognitivism, constructivism, and connectionism—offers a distinct lens through which to understand the complex processes of learning. Together, they provide a comprehensive framework that informs educational practices and research, helping educators to better facilitate learning in diverse contexts.

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Lesson 2.2.2. Online Learning Strategies and Models

Learning Outcomes

By the end of this lesson, learners will be able to:

- Understand the principles that underpin effective digital education and online teaching.
- Foster a sense of community and collaboration among online learners.
- Utilize feedback mechanisms to support continuous improvement in teaching and learning.
- Recognize and address the diverse needs and learning styles of online students.
- Apply educational theories such as behaviorism, cognitivism, constructivism, and connectivism to online teaching practices.
- Integrate the Elements of Effective Instruction Framework into online learning experiences to enhance student engagement and outcomes.

Lesson Content

Introduction

This lesson explores some principles that underpin effective digital education and online teaching, and how learning theories can inform approaches to teaching.

Instead of being confined to a mere binary decision, the landscape of online teaching presents a plethora of options and methodologies that can be tailored to suit diverse contexts. Hence, it is imperative to acquaint oneself with fundamental concepts and various tool categories, deliberate upon existing knowledge in this domain, adopt a flexible approach conducive to experimenting with online teaching methods, and carefully analyse the outcomes yielded by such endeavours (OU, 2017).

In the realm of online education, there exists a set of guiding principles known as the „Principles of Effective Online Teaching“. These principles serve as the foundation for a successful and enriching online learning experience:

- create a schedule;
- keep learners informed;
- foster a sense of community;
- ask for feedback; and
- recognise diversity (OU, 2017).

VIDEO 2.2.7. Online Learning Strategies [*duration 1:48 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88866/mod_book/chapter/2650/Online%20Learning%20Strategies.mp4

VIDEO 2.2.8. Things You Need to Know About Instructional Design for eLearning [*duration 6:45 minutes*]: https://www.youtube.com/watch?v=Tw-yjgmZueU&t=2s

Create a Schedule

First and foremost, wise educators emphasize the critical importance of **creating a structured schedule.** A well-organized timetable provides learners with a sense of stability and direction, which is essential in their virtual journey of knowledge acquisition. In the transition to an asynchronous online learning environment, it is common for students to expect that the teacher will always be available. Therefore, it is imperative to establish and communicate a clear schedule that delineates your availability to learners.

To effectively manage expectations and support student success, educators should establish specific times when they are available for student interactions, as well as periods when they are not. For those requiring synchronous support, scheduling drop-in tutorials can be an effective strategy. Additionally, it is crucial to provide learners with a comprehensive schedule of expectations, clearly outlining the milestones they should achieve by specific dates throughout the course.

This proactive approach ensures that students are aware of key deadlines and understand the progression of the course. Regular follow-ups are necessary when students miss core deadlines, to provide additional support and to keep them on track with the curriculum. By doing so, educators can foster an environment of accountability and support, facilitating a more structured and successful learning experience (OU, 2017).

Keep Learners Informed

Next, the guardians of online education emphasize the crucial importance of **keeping learners well-informed.** It is essential to consistently and frequently communicate information about core deadlines to ensure students remain aware of critical dates. Repetition is key in reinforcing these deadlines and helping students stay organized and on track.

For synchronous learning events, such as webinars and group tutorials, it is important to provide multiple reminders in the weeks and days leading up to each event. This helps ensure maximum participation and allows learners to plan accordingly. Clear and frequent communication about these events can significantly enhance student engagement and participation.

In the event of changes to planned activities, such as an absence where you will be unable to respond to messages for a few days, it is vital to inform learners well in advance. Clear communication regarding such changes helps manage expectations and prevents any disruption to the learning process. Additionally, designate an alternate contact person who can assist learners urgently if needed during your absence. This ensures that students always have access to support and guidance, maintaining the continuity of their learning experience (OU, 2017).

Foster a Sense of Community

Moreover, the educators should **foster a sense of community** among their digital disciples. Building community is important for online learning, where learners can readily drift away or feel isolated due to the nature of online engagement. So, think about steps to keep them together and engaged. Through virtual gatherings, collaborative projects, and interactive discussions, we can create a warm and inclusive environment where learners felt connected and supported.

In an online environment, the role of the teacher can become more supportive and collegiate, such that the learners understand that your primary role is to help them to succeed on the course. It can be useful to construct an individual relationship with each learner rather than always relying on mass or automated emails (OU, 2017).

Wenger's (1998) concept of 'communities of practice' (CoP) has gained traction in education over the past two decades. Wenger suggests that people who share a common goal or purpose can form a CoP through which they share insights and experiences. Members of a community are practitioners in a particular area. For example, they could be teachers in a subject area who discuss their ideas and experiences in a shared online space. Active participation in a CoP is a social process, and yet it enhances individuals' learning and can also increase their social capital through developing connections and recognition.

Ask for Feedback

Understanding the value of continuous improvement, wise mentors actively encourage their students to provide regular feedback. This practice is integral to ensuring that the learning experience remains dynamic and responsive to the needs of the students. Regularly checking in on how learners are progressing through the course materials and assessing their understanding is crucial. This allows

educators to evaluate whether students are adequately supported and to identify any areas where additional assistance may be required.

Students who respond negatively or do not respond at all warrant particular attention. These individuals may need tailored interventions to help them develop effective study strategies and regain their footing in the course. Providing targeted support to these students can significantly improve their learning outcomes and overall course satisfaction.

Online feedback mechanisms, such as surveys and discussion forums, offer a more immediate and formative means of gathering student feedback compared to traditional paper questionnaires (Donovan et al., 2006). These tools allow tutors to quickly identify and address any issues, facilitating a more agile and responsive teaching approach.

Additionally, engaging in peer observation with fellow online teachers can be extremely beneficial. This practice allows educators to share best practices, gain new perspectives on their teaching methods, and collaboratively improve their instructional strategies (Jones and Gallen, 2016; OU, 2017). By fostering a culture of continuous feedback and professional development, educators can enhance the quality of online education and better support their students' learning journeys.

Recognise Diversity

One of the primary advantages of the online learning environment is that it allows students to learn at their own pace and in their own way. It is essential to preserve the flexibility that online study offers by avoiding unnecessary restrictions on how students choose to engage with their learning materials.

Differentiated instruction plays a crucial role in this context. Online instructors can effectively tailor their teaching strategies to accommodate individual abilities, learning styles, and interests (Beasley and Beck, 2017). This personalized approach can significantly enhance student engagement and achievement. However, it is also important to provide a common framework or shared structure to ensure that all learners have a clear understanding of course expectations and milestones (OU, 2017).

Armed with these noble principles, educators embark on their quest to empower learners in the ever-expanding realm of online education. Guided by the unwavering belief that knowledge knows no bounds, they recognize that the pursuit of learning is a collaborative journey, one that requires flexibility, support, and a commitment to continuous improvement. By embracing the unique opportunities and challenges of online education, they strive to create an inclusive and dynamic learning environment where every student can thrive.

Elements of Effective Instruction Framework

The Elements of Effective Instruction Framework by the Great Schools Partnership outlines five intertwined elements of instructional practice that complement and enhance one another (see Figure 2.2.1):

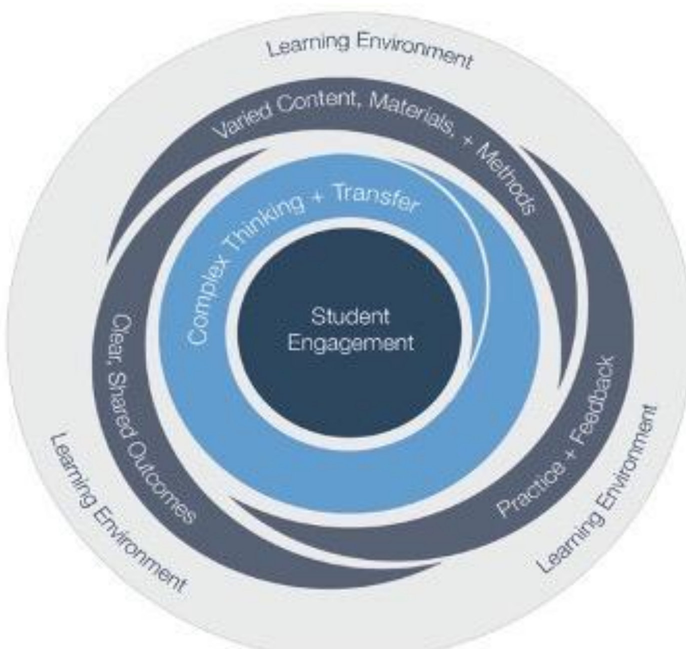


Figure 2.2.1. Elements of Effective Instruction Framework by the Great Schools Partnership https://www.greatschoolspartnership.org/resources/elements-of-effective-instruction/

1. Learning Environment

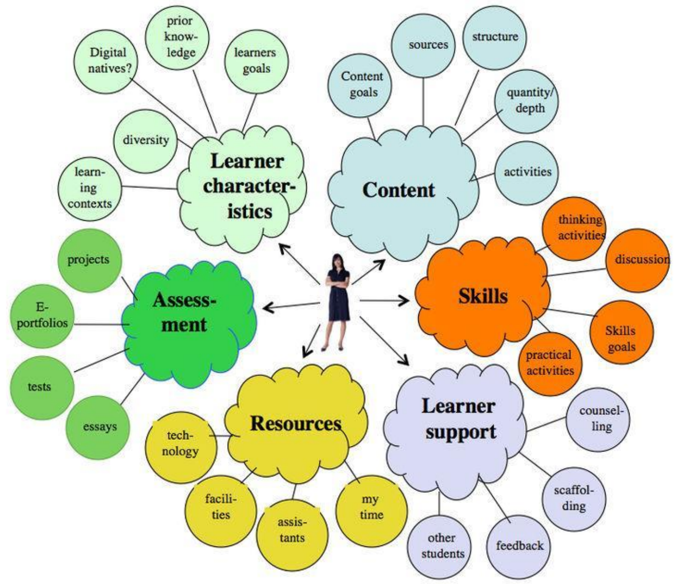
- A supportive and inclusive learning environment is foundational to effective instruction. It encompasses physical, emotional, and psychological aspects, ensuring that all students feel safe, respected, and valued. Creating a positive learning atmosphere fosters engagement and facilitates deeper learning.

2. Clear, Shared Outcomes
   - Clearly defined and communicated learning objectives are essential. These outcomes should be shared with students to provide a transparent roadmap of what is expected. When students understand the goals, they can better align their efforts and track their progress towards achieving them.
3. Varied Content, Materials, and Methods
   - Utilizing diverse content, materials, and instructional methods caters to different learning styles and needs. By incorporating a variety of resources and teaching techniques, educators can address individual differences, making learning more accessible and engaging for all students.
4. Practice and Feedback
   - Opportunities for practice and timely, constructive feedback are crucial for mastering new skills and concepts. Regular practice helps reinforce learning, while feedback guides students in refining their understanding and improving their performance. This iterative process is key to continuous improvement and skill development.
5. Complex Thinking and Transfer
   - Encouraging complex thinking and the ability to transfer knowledge to new situations is vital for developing critical thinking and problem-solving skills. Instruction should challenge students to analyze, synthesize, and apply what they have learned in various contexts, preparing them for real-world challenges and fostering lifelong learning.

When integrated into learning experiences, these elements foster student engagement with the ultimate goal of improving student outcomes and achievement.

Learning Environment

Learning Environment encompasses more than just the technical infrastructure of online instruction; it is a dynamic ecosystem shared by students, educators, families, and other stakeholders. At its core, it is a space that fosters collaboration, encourages inquiry, and embraces the value of learning from mistakes.



In this shared domain, the physical setting, established routines, and interpersonal connections play crucial roles in cultivating a sense of safety and belonging. By creating an environment that is physically, socially, and emotionally secure, learners are empowered to explore, take risks, and engage deeply with the learning process.

Central to a thriving learning culture are the relationships forged within the community. Positive and meaningful interactions between students, teachers, and other participants lay the groundwork for collaboration, trust, and mutual respect. These relationships form the bedrock upon which a productive and inclusive learning environment is built.

Ultimately, safety and respect are indispensable elements that underpin learner engagement and willingness to take intellectual risks. By prioritising these values, educators can create an environment where every individual feels valued, supported, and motivated to reach their full potential.

Physical Space and Routines. Physical Space and Routines serve as foundational elements in the creation of an effective and inclusive learning environment:

Establishment of clear and collaborative routines. Clear, consistent, and respectful routines, procedures, and expectations are collaboratively established with input from students. This ensures that students understand what is expected of them, when, and why, fostering a sense of ownership and accountability within the learning community.

Accessibility of tools and materials. Essential tools and materials are readily accessible to students, enabling seamless engagement with learning resources. By ensuring easy access to necessary resources, educators empower students to navigate their learning journey effectively and independently.

Flexibility in environmental configuration. The learning environment is adaptable and can be configured in various ways to accommodate different learning tasks and activities. This flexibility enables educators to optimize the physical space to best suit the needs of diverse learners and facilitate varied instructional approaches.

Empowerment for personalised learning. Students are empowered to utilise and navigate the learning environment in ways that align with their individual learning preferences and needs. This autonomy fosters a sense of agency and independence, enabling students to take ownership of their learning process and pursue personalised pathways to academic success.

Educational Theories and Digital Education

How Can Educational Theories Help You Take Your Teaching Online?

Educational theories offer valuable insights that can significantly enhance the transition to online teaching. When exploring the benefits of online education for learners, four key theories provide a framework for effective online instruction: behaviorism, cognitivism, constructivism, and connectivism. These theories underpin the five principles of effective online teaching discussed earlier in this lesson. Understanding their core concepts can be instrumental in successfully navigating the online teaching environment (OU, 2017).

2. Behaviourism:

    - Behaviourism focuses on observable behaviors and the ways they can be shaped by the environment through reinforcement and punishment. In an online setting, this translates to designing learning activities that provide clear stimuli and responses, such as quizzes and immediate feedback. This approach can help reinforce correct behaviors and facilitate the learning of new skills through repetition and reinforcement.

3. Cognitivism:

   - Cognitivism emphasizes the importance of internal mental processes and how they influence learning. It considers how learners process, store, and retrieve information. Online educators can leverage this theory by organizing content in a logical and structured manner, using multimedia to support different cognitive processes, and incorporating activities that promote critical thinking and problem-solving.

4. Constructivism:

   - Constructivism posits that learners construct their own understanding and knowledge through experiences and reflection. In the online environment, this can be achieved by creating interactive and engaging activities that encourage exploration and discovery. Discussion forums, group projects, and problem-based learning tasks can help learners build knowledge collaboratively and reflect on their learning journey.

5. Connectivism:

   - Connectivism is a contemporary theory that highlights the role of social and technological networks in learning. It acknowledges the impact of digital information and communication technologies on how knowledge is created and shared. Online instructors can apply connectivist principles by fostering a connected learning community, encouraging the use of social media and other digital tools for collaboration, and providing opportunities for learners to connect with experts and resources beyond the classroom.

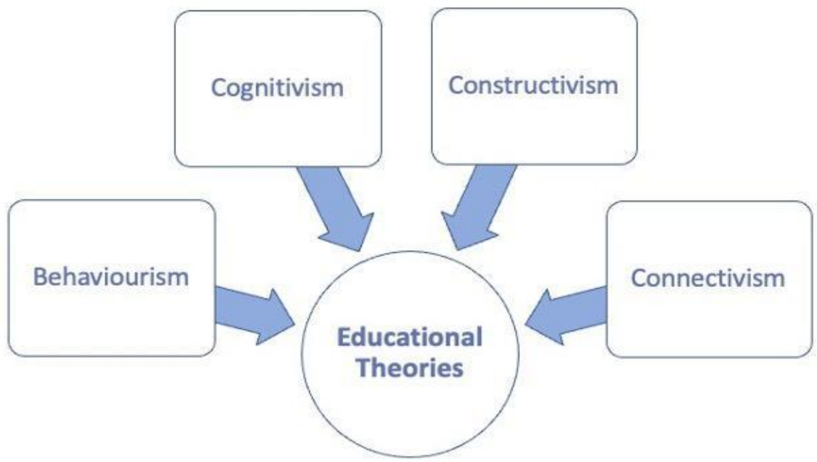


Figure 2.2.3. Educational theories informing online teaching

By keeping these theories in mind, educators can design and deliver online courses that are not only effective but also engaging and responsive to the diverse needs of their learners. Integrating these theoretical perspectives helps create a robust online learning environment that supports meaningful and lasting educational experiences.

Conclusion

By prioritizing the establishment of clear routines, ensuring the accessibility of resources, embracing flexibility in environmental design, and empowering students in their learning endeavors, educators can cultivate a dynamic and supportive educational environment. This holistic approach enhances student engagement, promotes positive learning outcomes, and supports overall well-being.

Clear routines provide structure and predictability, helping students to navigate their educational journey with confidence. Ensuring resources are easily accessible removes barriers to learning, allowing all students to fully participate and benefit from the educational opportunities provided. Embracing flexibility in the design of the learning environment accommodates diverse learning styles and needs, fostering an inclusive atmosphere where every student can thrive.

Moreover, by empowering students and giving them agency in their learning, educators foster a sense of ownership and motivation that drives deeper engagement and commitment. This empowerment encourages students to take an active role in their education, developing critical thinking skills and independence that will serve them well beyond the classroom.

Together, these strategies create a nurturing and effective educational space that not only enhances academic performance but also contributes to the holistic development of each student.

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Lesson 2.2.3. Pedagogical Approaches for Online Teaching

Learning Outcomes

By the end of this lesson, learners will be able to:

- Explain the principles and importance of active learning in online education.
- Identify various active learning strategies suitable for online teaching.
- Develop online learning activities that promote engagement, collaboration, and critical thinking.
- Understand the constructive alignment approach to ensure alignment between learning outcomes, activities, and assessments.
- Address common challenges in online learning.
- Implement effective online course design strategies, taking into account students' prior knowledge, learning preferences, and the unique context of each teaching situation.
- Foster a sense of community and social presence in the online learning environment.

Lesson Content

Introduction

This lesson introduces **effective strategies for fostering digital education** focusing on active learning, interaction, and collaboration in online education. Active learning plays a vital role in virtual classrooms, as it keeps students engaged and connected. Through activities like discussions, group tasks, and interactive assignments, students not only enhance their retention but also cultivate critical thinking skills. Collaborative activities promote teamwork and communication, essential for success in digital environments. Additionally, active learning in online education is adaptable to various formats, accommodating students' individual learning preferences and pace. Overall, by encouraging engagement, retention, critical thinking, collaboration, and flexibility, active learning enhances student outcomes in the online environment.

VIDEO 2.2.9. Pedagogical Approaches for Online teaching [*duration 1:52 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88868/mod_book/chapter/2661/Pedagogical%20Approaches%20for%20Online%20Teaching.mp4

Active Learning

Active learning constitutes an instructional approach that engages learners actively within the learning process. This pedagogical approach involves learners in meaningful activities, encouraging them to both undertake actions and think the things they are doing. By engaging in active learning, students interact meaningfully with course content, their peers, and educators, utilising various educational tools and technologies, thereby fostering cognitive engagement. Unlike passive modalities like traditional lectures, active learning necessitates a higher degree of learner responsibility, but instructor guidance is still crucial.

Central to active learning is the construction of individual understanding, wherein learners establish connections between pre-existing knowledge and novel experiences, subsequently reflecting on the evolution of their comprehension. Embedded within these learning activities are assessment tasks that afford students the opportunity to demonstrate mastery of the prescribed learning objectives.

Active learning doesn’t simply make learning more interesting for students. It also promotes:

- higher-level thinking,
- independent study skills,

- communication skills and
- problem-solving abilities.

These skills are transferable to work, further study and personal and professional life, and will set students up for whatever they choose to do next (OU, n.d.).

Developing Active Learning

Active learning is particularly important in online education, where students aren't in the same location as their peers. Instructors should start thinking about active learning from the moment they start planning their online learning materials and incorporate strategies to encourage active learning, application, interaction, participation, and collaboration in the online environment. In an active learning environment, learners are immersed in experiences within which they engage in meaning-making inquiry, action, imagination, invention, interaction, hypothesizing and personal reflection (Cranton, 2012).

Active learning is about what the student does rather than what the teacher does (OU, n.d.). Most of the activities should be designed to prompt students not simply to read, see or listen to information but to search for it, process it, discuss it, present it, reflect on it, and apply it in real or simulated scenarios to which they can relate. Incorporating active learning in online learning environments is crucial because it includes collaboration, exchanging ideas, and fostering an inclusive environment.

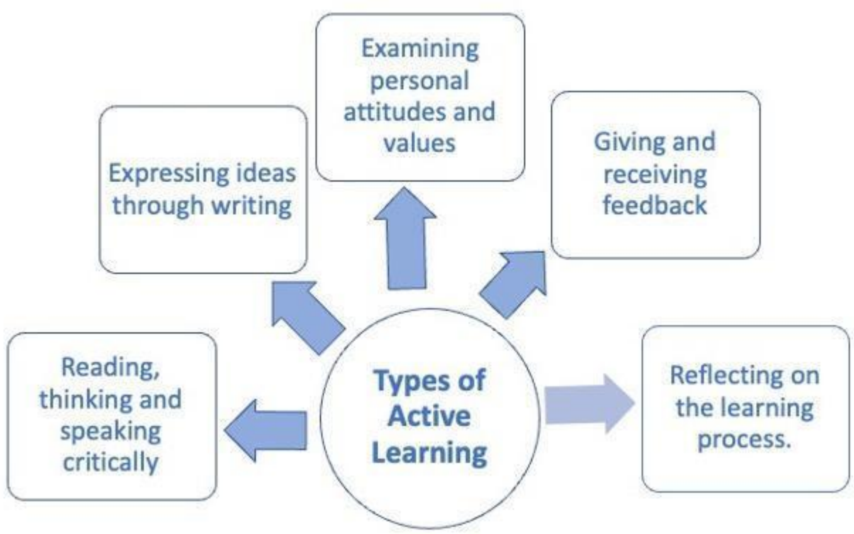

Figure 2.2.4. Types of Active Learning

There are a variety of active learning strategies described in the literature. Many university websites provide lists, guides, and resources for active learning strategies:

- Iowa State University Center for Excellence in Learning and Teaching presents 226 Active Learning Strategies;
- Purdue University offers Active Learning Strategies and Resources;
- University of Leicester active learning strategies.

Principles of Active Learning

Barnes (1989) suggested the following principles of active learning:

- **Purposive:** the relevance of the task to the students' concerns.
- **Reflective:** students' reflection on the meaning of what is learned.
- **Negotiated:** negotiation of goals and methods of learning between students and teachers.
- **Critical:** students appreciate different ways and means of learning the content.
- **Complex:** students compare learning tasks with complexities existing in real life and making reflective analysis.
- **Situation-driven:** the need of the situation is considered in order to establish learning tasks.
- **Engaged:** real life tasks are reflected in the activities conducted for learning.

The instructional design of online courses, taken together with active learning, deals with motivation, challenge, individual learning preferences, and social interaction. When instructors incorporate active learning techniques closely tied to desired learning outcomes, they can transform practical experiences into the online classroom environment. Experiential opportunities create authentic opportunities for sharing and transferring knowledge of information to learners in order to meet the required course learning performance goals and standards. These examples cultivate learner development, build on learners' previous knowledge, and help learners develop in-depth knowledge and enhance team building, problem-solving, analysis, and critical thinking skills. In this section we shared just a few ways faculty can engage learners by incorporating active and experiential learning activities into online courses.

Active Learning Techniques

There are a broad range of active learning techniques (see Figure 2.2.5) and active teaching and learning methodologies (see Figure 2.2.6) that can be integrated into online teaching and learning.

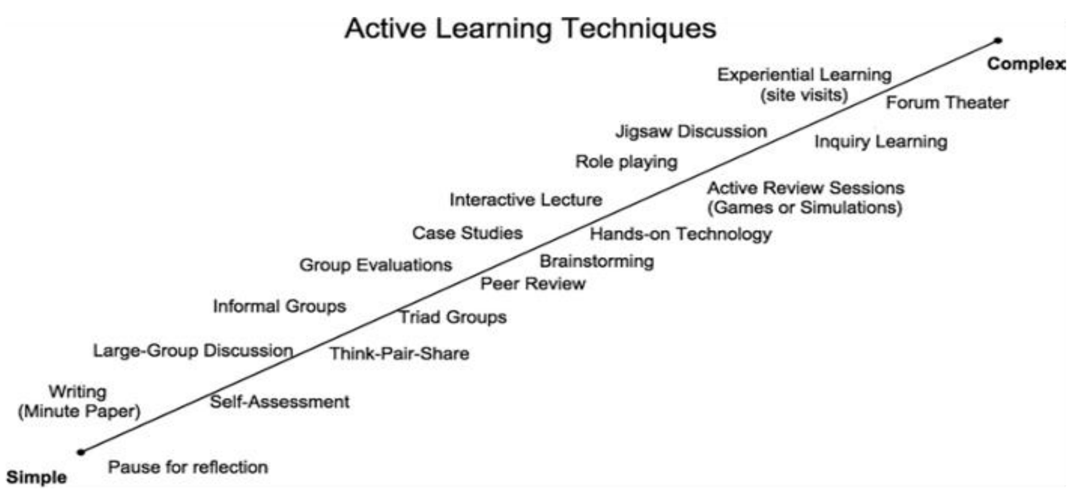

Figure 2.2.5. Active learning techniques

(O'Neal and Pinder-Grove, Center for Learning and Teaching, University of Michigan)

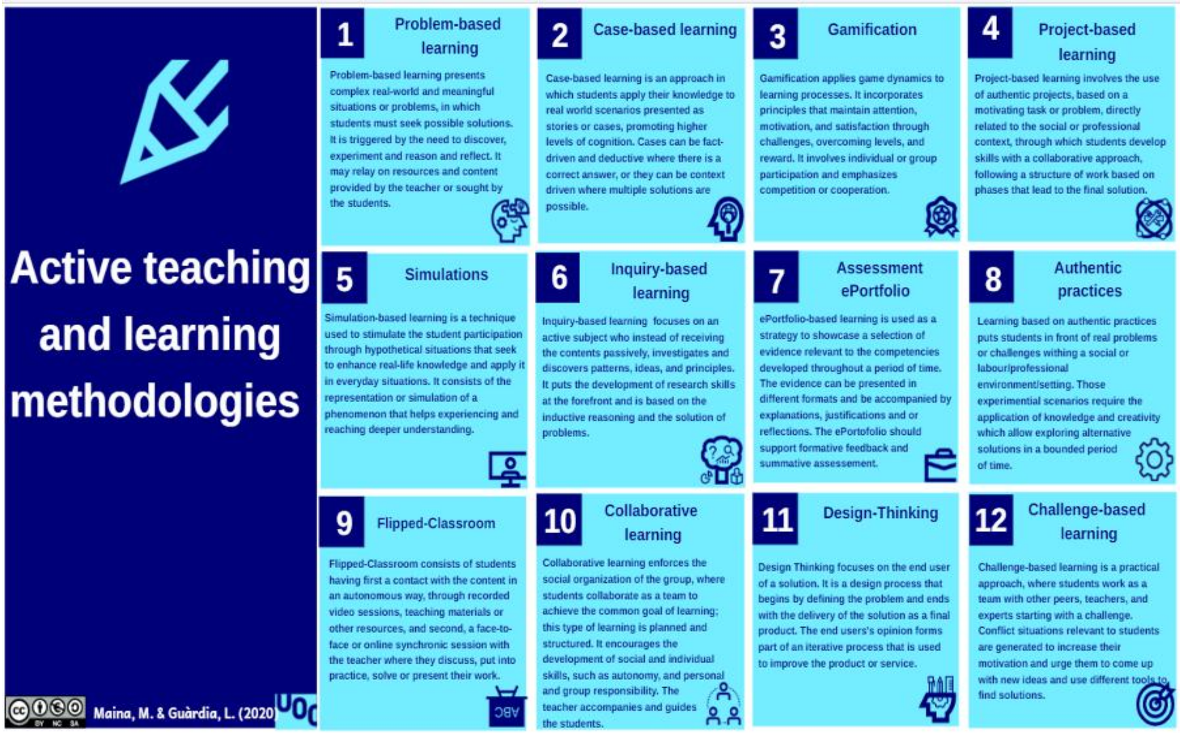

Figure 2.2.6. Active teaching and learning methodologies (Maina and Guàrdia, 2020).

Constructive Alignment

Course Units should be designed so that the Learning Activities and Assessments are aligned with one another and support and measure students' achievement of the unit's Intended Learning Outcomes (ILOs).

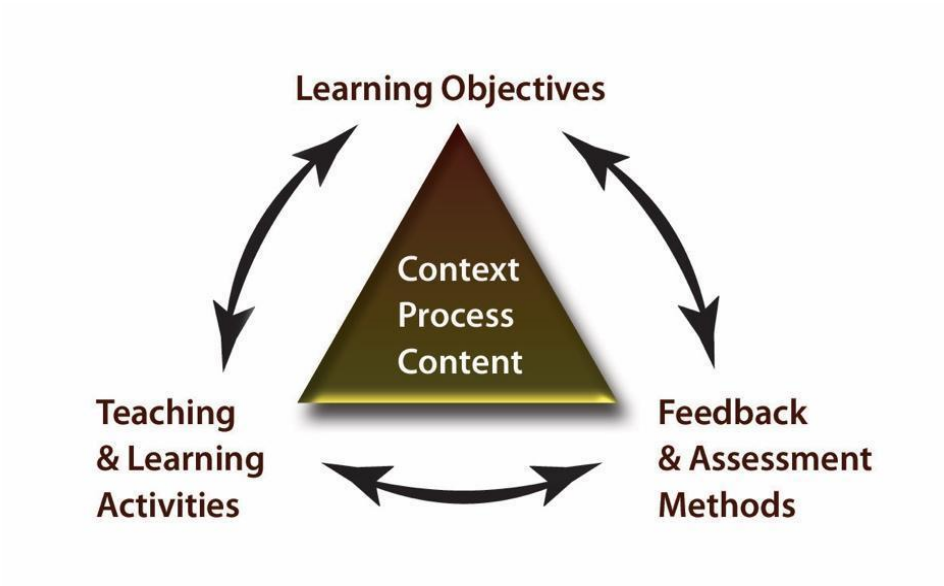

Figure 2.2.7. Constructive alignment (Doug Schaefer)

Constructive Alignment (CA) is an approach to teaching in which learning outcomes are the foundation of all teaching decisions. Therefore, all learning experiences in a course (whether technological or not) must be rooted in the course Learning Objectives. So, before adding an activity or learning experience, ask yourself, "Which Learning Outcome does this support?"

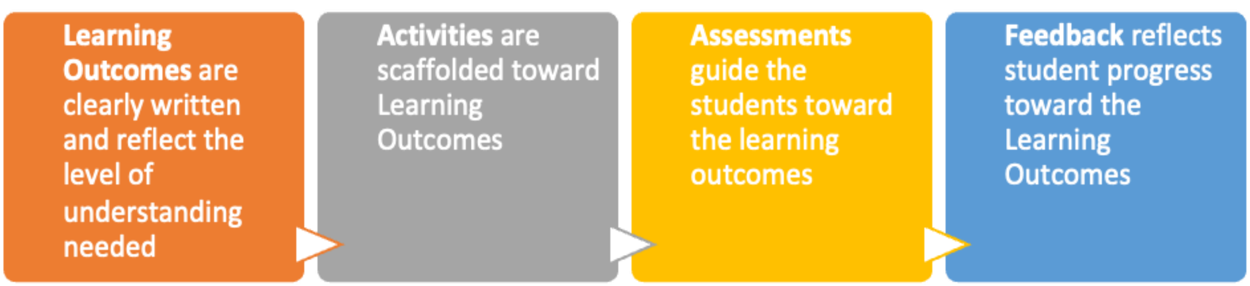

Figure 2.2.8. Parts of Constructive Alignment

Course Units are designed so that the Learning Activities and Assessments are aligned with one another and support and measure students' achievement of the unit's Intended Learning Outcomes (ILOs). "Constructive alignment is a design for teaching in which what it is intended students should learn and how they should express their learning is clearly stated before teaching takes place. Teaching is then designed to engage students in learning activities that optimise their chances of achieving those outcomes, and assessment tasks are designed to enable clear judgments as to how well those outcomes have been attained" (Biggs, 2014, pp. 5-6). Alignment occurs when the learning activities that we ask students to engage in help them to develop the knowledge, skills and understandings intended for the unit and measured by our assessment. A constructively aligned unit capitalises on the powerful effect of assessment on students' learning experiences. If assessment drives students' learning, then students are most likely to achieve our intended outcomes if the assessment is aligned with our intentions.

The Framework of Constructive Alignment

- The framework of constructive alignment to unit design:
- Identify the intended learning outcomes (ILOs).
- Design assessment tasks to measure attainment of the learning outcomes.
- Plan learning activities to enable students to develop the skills, knowledge and understandings described in the ILOs and measured by assessment.
- Choose the content required to support the learning activities.

Strategies to Course Design

Several strategies for effective online course design have been proposed. For example, Active Learning Cheat Sheet. 10 Steps to getting started provides the following 10 steps:

- Create an open and safe environment.
- Set a goal for the activity.
- Choose the right exercise.
- Identify preparation for the exercise.
- Consider links to other class elements.
- Plan how you will introduce the activity.
- Plan the logistics.
- Consider how you will judge success.
- Just do it.
- Iterate and expand.

In the vast expanse of online education, the art of course design emerges as a paramount endeavour, requiring careful planning, strategic foresight, and a keen understanding of pedagogical principles. Among the myriad strategies proposed to navigate this terrain, the Active Learning Cheat Sheet stands as a guiding beacon, offering a roadmap for educators embarking on the journey of online course design.

At its core lies a comprehensive framework encapsulated within 10 succinct steps, each a vital component in the tapestry of effective online learning experiences. The journey begins with the **creation of an open and safe environment**, a virtual sanctuary where learners feel empowered to explore, inquire, and collaborate without fear of judgment or reprisal. Here, the seeds of trust and camaraderie are sown, laying the foundation for meaningful engagement and shared discovery.

With the stage set, the educator charts a course by **setting clear goals for each learning activity**, guiding students towards a specific destination and imbuing their efforts with purpose and direction. Like a compass guiding a ship through turbulent waters, these goals serve as beacons of clarity, illuminating the path ahead and orienting learners towards success.

Next, the educator carefully **selects the right exercises** to achieve these goals, choosing activities that are not only engaging and interactive but also aligned with the desired learning outcomes. Whether it be discussion forums, collaborative projects, or interactive simulations, each exercise is thoughtfully curated to maximise student engagement and deepen understanding.

Preparation is key to success, and so the educator diligently identifies the resources and materials needed **to support each exercise**, ensuring that students have the tools and knowledge necessary to excel. From readings and videos to interactive tools and supplementary resources, every element is meticulously curated to enrich the learning experience.

But learning does not occur in isolation; it is woven into the fabric of a larger educational tapestry. Thus, the educator considers the **links between each activity and other course elements**, fostering continuity and coherence across the curriculum.

With the groundwork laid, the educator **plans the introduction of each activity**, setting the stage for engagement and signaling its importance to students. Clear instructions, learning objectives, and expectations are communicated, empowering students to approach the task at hand with confidence and purpose.

Logistical considerations are paramount in the realm of online education, and so the educator plans meticulously to ensure a seamless experience for students. From technical requirements to scheduling constraints, every detail is attended to, minimizing barriers to participation and maximizing accessibility.

As the activity unfolds, the educator considers **how success will be judged**, identifying criteria for assessment and evaluation that are aligned with the overarching learning goals. Through formative feedback and reflection, students are guided towards mastery, their progress celebrated and their challenges addressed with empathy and support.

But perhaps the most important step of all is to **simply take action** – to dive headfirst into the realm of active learning and embrace the journey with enthusiasm and determination. With each iteration, the educator **refines their approach**, incorporating feedback and insights gleaned from experience to continuously improve and expand upon their practice.

In this way, the Active Learning Cheat Sheet serves as a guiding compass, navigating educators through the intricate landscape of online course design and empowering them to create transformative learning experiences that inspire, engage, and empower students to reach new heights of knowledge and understanding.

Another resource, How to Plan Effective Lessons for Your Online Classroom, suggest 7 major steps:

- Understand Your Students
- Set a Clear Objective for the Lesson
- Incorporate Visuals, Visuals, and More Visuals
- Keep Your Teaching Modules Short
- Keep a Clear and Consistent Structure
- Add Assignments and Homework
- Evaluate, Reflect and Revise.

Buck Institute for Education also propose seven steps:

- Design & Plan
- Align to Standards
- Build the Culture

- Manage Activities
- Scaffold Student Learning
- Assess Student Learning
- Engage & Coach

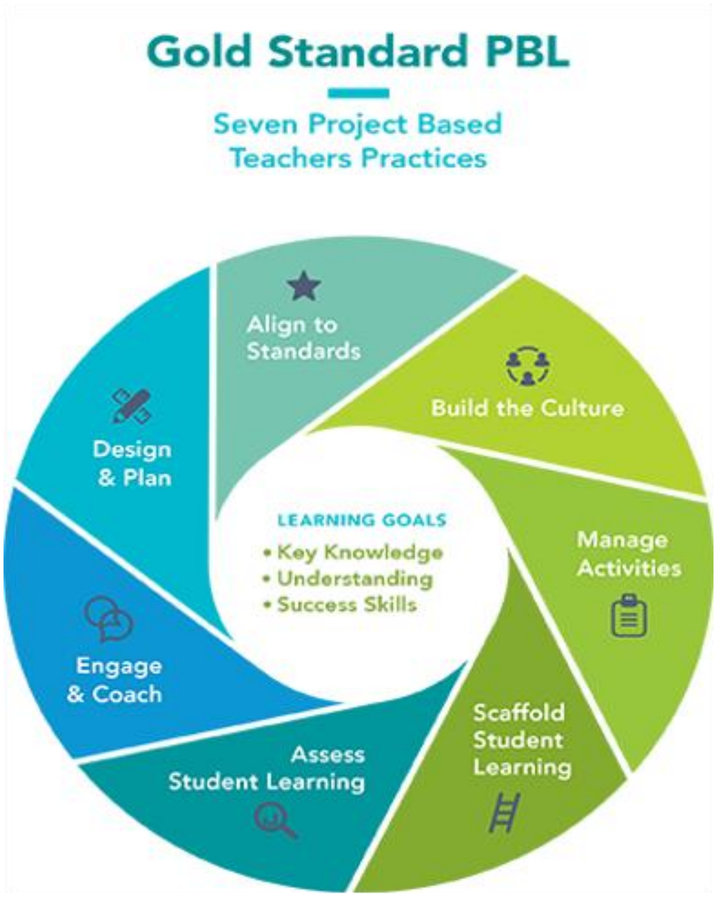

Figure 2.2.9. Strategies to Course Design

(Buck Institute for Education, Creative Commons)

Metacognition

Metacognition, often described as 'thinking about thinking', plays a crucial role in student learning in online education. Its significance lies in its ability to enhance students' awareness of their own learning processes, strategies, and cognitive strengths and weaknesses. In online education, where learners often have greater autonomy and responsibility for their learning, metacognitive skills become even more vital. Metacognition can contribute to student learning in the online environment in the following way:

- *Self-regulated learning:* Metacognition empowers students to take control of their learning journey by enabling them to set goals, plan strategies, monitor their progress, and adjust their approaches as needed. In an online setting, where students may not have immediate access to instructors, self-regulated learning skills are essential for maintaining motivation and staying on track with coursework.

- *Adaptability:* Online education often presents diverse learning materials and formats, from text-based readings to multimedia presentations. Metacognitive awareness allows students to assess which strategies work best for them in navigating these varied resources, adapting their study techniques to suit different learning environments and content types.

- *Critical thinking*: Metacognition fosters critical thinking skills by encouraging students to reflect on the validity and reliability of information encountered in online courses. Through metacognitive processes such as evaluating evidence, identifying biases, and considering alternative perspectives, students can develop a more discerning approach to online content consumption and analysis.

- *Problem-solving:* When faced with challenges or obstacles in their online studies, metacognitive learners are better equipped to identify the root causes of their difficulties and implement effective solutions. By reflecting on their problem-solving processes and learning from past experiences, students can develop more robust strategies for overcoming academic hurdles.

- *Engagement and motivation*: Learners with metacognitive skills are more likely to be actively engaged in their online courses, as they possess a deeper understanding of their own learning preferences, interests, and motivations. By aligning course content and activities with their personal goals and aspirations, students can sustain their enthusiasm for learning throughout the online learning experience.

- *Transfer of learning:* Metacognition facilitates the transfer of learning from one context to another, allowing students to apply knowledge and skills gained in online courses to real-world situations. By reflecting on how they have applied their learning in different contexts and considering the underlying principles at play, students can enhance their ability to transfer knowledge effectively.

Figure 2.2.10. Metacognition
(https://www.queensu.ca/teachingandlearning/modules/students/24_metacognition.html)

In essence, metacognition serves as a guiding compass for students navigating the complexities of online education, empowering them to become self-directed, adaptive, and critical thinkers who actively engage with course materials, collaborate with peers, and persist in the pursuit of their academic goals.

Understanding Students' Learning Challenges

Throughout the process of learning, students often experience a variety of cognitive, motivational, and affective challenges that can significantly impact their educational journey. These challenges, intricately interwoven and mutually influential, emanate from the complex interplay of cognitive processes, motivational and affective states, and social dynamics within the learning environment. As such, understanding the multifaceted nature of these challenges is essential for educators seeking to support their students effectively.

Cognitive challenges encompass a broad spectrum of obstacles that impede students' acquisition, processing, and retention of knowledge. These may manifest as difficulties in understanding complex concepts, solving problems, or synthesizing information from various sources. Factors such as cognitive load, information processing speed, and working memory capacity can all influence the extent to which students grapple with these challenges. Moreover, individual differences in cognitive styles and learning preferences further contribute to the diversity of cognitive obstacles students may encounter.

Motivational and affective challenges arise from students' internal drives, attitudes, and emotional states, all of which play pivotal roles in shaping their engagement and perseverance in learning tasks. A lack of intrinsic motivation, fear of failure, or feelings of anxiety and self-doubt can hinder students' willingness to invest effort and persist in the face of challenges. External factors, including perceived relevance of the material, instructional methods, and feedback mechanisms, also exert significant influence on students' motivational and affective experiences.

Furthermore, **social dynamics** within the learning environment serve as both catalysts and barriers to students' learning experiences. Peer interactions, group dynamics, and classroom norms all contribute to the social context within which learning occurs. Positive social interactions can foster collaboration, cooperation, and a sense of belonging, enhancing students' motivation and engagement. Conversely, interpersonal conflicts, social comparisons, or feelings of isolation can undermine students' confidence and impede their learning progress.

Crucially, students bring with them a wealth of prior knowledge, experiences, and learning strategies that shape their perceptions and responses to new learning situations. This existing knowledge base, combined with the unique dynamics of the current course and classroom environment, profoundly influences students' motivation to engage with course material and participate actively in learning activities. Recognising and leveraging these pre-existing assets can be instrumental in fostering a supportive and inclusive learning environment that meets the diverse needs of all students.

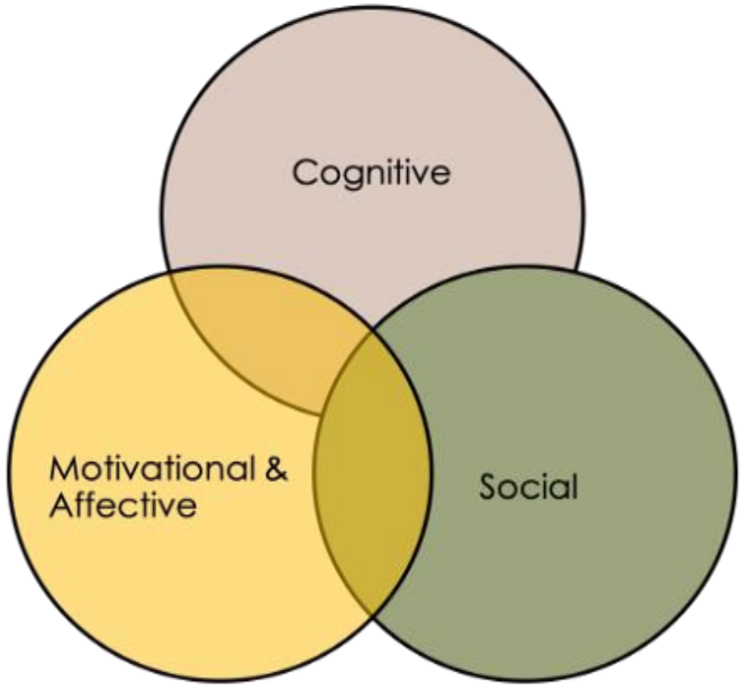

Figure 2.2.11. Students' Learning Challenges

Thus, the challenges students face during the learning process are multifaceted and complex, stemming from the intricate interplay of cognitive, motivational/affective, and social factors. By understanding and addressing these challenges holistically, educators can create learning experiences that empower students to overcome obstacles, cultivate resilience, and achieve their full potential.

Identifying the Problem

As an instructor, one of the first steps to supporting student learning is identifying the instructional challenges that can arise when students are learning the content and developing intellectual skills needed in their disciplines. Keeping the course you identified above in mind, you can complete the Instructional Challenges Inventory. You will rate instructional challenges in your class on a scale ranging from "not a problem" to "a big problem". Upon completion of the inventory, take a few moments to identify the "big problems" students experience in your course.

Identify Prior Knowledge and Prior Experience

Students come into an online course with a broad range of backgrounds, educational experiences, and prior knowledge and skills. Current research on learning suggests that learning is determined by what the learner already knows about the topic or related topics. If the pre-existing knowledge is correct and consistent with the new information, the effect on learning is positive. However, if prior knowledge is full of misconceptions, or conflicts with new information, the effect on new learning can be negative.

Identifying the prior knowledge and prior experiences of students in an online course is crucial for designing effective instruction, tailoring learning experiences to individual needs, and promoting meaningful engagement. Here are several strategies for identifying and assessing students' prior knowledge and experiences:

Pre-course surveys: Administer pre-course surveys or questionnaires that inquire about students' backgrounds, interests, and experiences related to the course topic. Ask open-ended questions to encourage students to reflect on their prior knowledge and experiences in relevant areas. Additionally, include questions about their learning preferences, strengths, and areas of improvement.

Diagnostic assessments: Use diagnostic assessments at the beginning of the course to gauge students' baseline understanding of key concepts or skills. These assessments can take various forms, such as quizzes, concept maps, or problem-solving tasks. Analyse students' responses to identify common misconceptions, areas of strength, and gaps in understanding.

Review of prerequisite courses: If your online course has prerequisite courses or recommended readings, review the curriculum and learning objectives of these courses to ascertain the foundational knowledge and skills that students are expected to possess. This can help you assess the readiness of students to engage with more advanced material in your course.

Analysis of assignments and projects: Review any assignments, projects, or portfolios that students may have completed in prior courses or professional experiences. Look for evidence of relevant skills, knowledge, and accomplishments that can inform your understanding of students' prior learning experiences and achievements.

Self-assessment activities: Incorporate self-assessment activities into your course design, where students can reflect on their own strengths, weaknesses, and prior experiences related to the course content. Encourage students to set personal learning goals based on their self-assessment and provide opportunities for them to revisit and revise these goals throughout the course.

Online discussion forums: Use online discussion forums or collaborative platforms to facilitate peer-to-peer interactions where students can share their perspectives, insights, and experiences related to course topics. Encourage students to engage in reflective discussions and dialogue about how their prior knowledge and experiences inform their understanding of new concepts.

Individual consultations: Offer opportunities for individual consultations or office hours where students can meet with you virtually to discuss their background, goals, and any questions or concerns they may have about the course. Use these interactions to build rapport with students and gain deeper insights into their unique learning profiles.

By employing a combination of these strategies, educators can gather valuable information about students' prior knowledge and experiences, allowing them to design instructional activities that build upon existing foundations, address misconceptions, and scaffold learning effectively in the online course environment.

No 'Best Practice' For Online Course Design

However, there is no 'best practice' for online course design, because this is contextual to each teaching and learning situation and discipline area. We should consider the content, purposes, and instructional strategies as well as how the instruction is represented and controlled through available technology tools.

The starting point should be

- understanding student needs,
- developing engaging activities,
- building a sense of community,
- employing discussion and reflections during presentations,
- providing tips, hints and tools for achieving these goals.

Conclusion

Pedagogical approaches for online teaching have evolved significantly, driven by the need to address the unique challenges and opportunities of digital education. Central to effective online pedagogy is the constructivist approach, which emphasizes active, student-centered learning. This approach leverages interactive tools such as discussion forums, collaborative projects, and peer assessments to foster a dynamic learning environment. Additionally, the flipped classroom model has gained traction, where students engage with lecture materials asynchronously and use synchronous sessions for interactive, application-based activities.

Another critical aspect is the use of multimodal content delivery, incorporating videos, readings, quizzes, and simulations to cater to diverse learning styles and keep students engaged. Formative assessment is emphasized to provide ongoing feedback and support, utilizing tools like automated quizzes, e-portfolios, and reflective journals.

Furthermore, social presence and community-building are crucial in online settings to combat isolation and enhance motivation. Strategies include regular instructor-student and student-student interactions, virtual office hours, and collaborative tools like group projects and peer review systems.

Effective online teaching also requires adaptability and continuous improvement. Instructors must be proficient with digital tools and platforms, and stay updated with emerging technologies and pedagogical strategies through professional development. This ongoing refinement ensures that online education remains engaging, effective, and equitable for all learners.

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Self-Assessment Quiz

Test your knowledge by taking the **Self-Assessment Quiz** (https://open.ktu.edu/mod/quiz/view.php?id=17823) included in the 2nd Topic, "Learning Theories and Digital Education" of the MOOC "Digital Education" (https://open.ktu.edu/course/view.php?id=194).

TOPIC 2.3. Digital Tools for Education

Lesson 2.3.1. Learning Management Systems

Learning Outcomes

By the end of this lesson, learners will be able to:

- Understand the historical context and evolution of Learning Management Systems (LMS).
- Identify key features and functionalities of modern LMS.
- Evaluate the impact of LMS on educational practices.
- Analyze popular LMS platforms and their unique characteristics.
- Recognize the challenges and considerations in implementing and managing LMS.
- Develop strategies to address common challenges associated with LMS use.

Lesson Content

Introduction

In the contemporary educational landscape, the proliferation of digital technologies has profoundly transformed the ways in which knowledge is disseminated and acquired. Among these technologies, Learning Management Systems (LMS) have emerged as pivotal tools that facilitate the administration, documentation, tracking, reporting, and delivery of educational courses, training programs, or learning and development programs. This lesson delves into the multifaceted dimensions of LMS, examining their evolution, functionalities, and impact on the learning environment.

Learning Management System is a software tool that allows you to create, deliver, and report on training courses and programs. There are many LMSs to choose from, each offering different features and capabilities. Every institution has different training needs, making identifying and selecting the ‘right’ LMS a daunting process.

VIDEO 2.3.1. Power of Learning Management Systems [*duration 2:12 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88873/mod_book/chapter/2675/LMS.mp4?time=1721087597620

VIDEO 2.3.2. What is Learning Management System? [*duration 2:04 minutes*]: https://www.youtube.com/watch?v=ezbJwaLmOeM&t=3s

Historical Context and Evolution

Weller (2023) notes that LMS is arguably the most successful education technology and the one that has had the biggest impact on digital education. The origin of LMS can be traced back to the early days of computing. In the 1960s and 1970s, computers were used primarily for scientific and military purposes. However, the potential for computer-assisted instruction in education was recognized, leading to the development of Computer-Based Training (CBT) systems which laid the foundation for what would later become the LMS (Kapadia, 2024).

Here are the key LMS milestones:

- 1924: Sidney Pressey invented the first “teaching machine,” which resembled a typewriter with a window.

- 1960: Dr. Donald Bitzer created PLATO (*Programmed Logic for Automatic Teaching Operations*), a computer-based training program that allowed learners to monitor their own progress.
- 1968: The HP-9100A calculator, developed by Hewlett Packard, introduced computational abilities that paved the way for future LMS systems.
- 1983: Project Athena, developed by MIT, allowed learners to access files from any computer on campus.
- 2002: Moodle, the first open-source LMS, was introduced. This platform allowed learners to choose the content they wanted, enabling personalized learning (Kapadia, 2024).

The 1980s marked a significant transformation with the advent of the internet. This era witnessed the emergence of eLearning platforms and a shift towards web-based training, integrating the internet and LMS. Educational institutions and corporations began to adopt online learning as a cost-effective and efficient method for delivering training. During this period, pioneering companies such as SoftArc, GeoMatrix Data Systems, and CourseInfo made crucial advancements in eLearning. Today, the global market for online learning has reportedly grown by over 900% since its inception in 2000, making it the fastest-growing segment in the education industry. Early eLearning platforms introduced essential features like course management, discussion boards, and assessment tools, establishing the foundation for modern LMS (Kapadia, 2024).

The early 1990s marked the inception of modern Learning Management Systems (LMS), distinguished by a broad array of advanced features. These included user management, content creation and management, reporting, and integration capabilities, which became standard in contemporary LMS (Kapadia, 2024).

A pivotal development during this period was the introduction of SCORM (Sharable Content Object Reference Model). SCORM established a groundbreaking standard for eLearning content creation and sharing, enabling content creators to produce standardized learning materials that could be seamlessly shared and deployed across various LMS platforms. This innovation promoted interoperability and collaboration within the learning industry, breaking down barriers and facilitating the exchange of educational resources across institutions and organizations (Kapadia, 2024).

By the late 2000s and early 2010s, most LMS vendors recognized the necessity of mobile LMS solutions and began developing apps with responsive design to integrate with their systems. These apps facilitated the creation of mobile-friendly learning solutions, making LMS more accessible and intuitive for users.

Currently, 74% of learners utilize mobile devices for eLearning, underscoring the importance of mobile-friendly platforms in modern education. Moreover, the advent of mobile devices significantly transformed how organizations deliver training and create corporate learning programs. The ability to access information on the go enabled companies to provide extensive training programs without the need for costly classroom-based sessions. This shift has made corporate learning more flexible and efficient, aligning with the dynamic needs of the contemporary workforce (Kapadia, 2024).

With the rise of artificial intelligence (AI), eLearning is experiencing a paradigm shift towards more personalized learning solutions, fostering a more engaging and effective educational environment. As these technologies advance, we can anticipate the regular integration of AI-driven features in Learning Management Systems (LMS), like:

- Automated content generation;
- Adaptive learning paths;
- Personalized assessment tools;
- Skill gap analysis;
- Intelligent grading and feedback;
- Virtual tutors and chatbots;
- Learning resource recommendations (Kapadia, 2024).

Key Features and Functionalities

Modern LMS are equipped with a myriad of features designed to enhance the learning experience and streamline educational processes.

Core functionalities typically include:

- Content Management: Enabling the creation, storage, and distribution of learning materials in various formats, such as text, video, and interactive media.

- Assessment and Evaluation: Facilitating the design and administration of quizzes, tests, and assignments, alongside tools for grading and providing feedback.
- Communication and Collaboration: Offering forums, chat rooms, and messaging systems to foster interaction between learners and educators, as well as among peers.
- Tracking and Reporting: Allowing educators to monitor learner progress, generate performance reports, and identify areas needing intervention.
- Customization and Personalization: Supporting the tailoring of learning experiences to meet individual learner needs and preferences.

Benefits of LMS in online teaching include:

- Improved accessibility and flexibility: LMS offer anytime, anywhere access to course materials, catering to diverse learning styles and schedules.
- Enhanced communication and collaboration: Facilitates communication, collaboration, and community building among instructors and students.
- Streamlined assessment and feedback: Centralized platforms reduce administrative burden and enhance timely feedback.
- Data-driven decision-making: Analytics provide valuable insights, enabling informed decisions about teaching approaches and interventions.
- Centralised resource repository: LMS serve as a repository for all course materials, assignments, and communication, ensuring easy access.

Impact on Educational Practices

The integration of LMS into educational institutions and corporate training programs has ushered in a paradigm shift in how learning is approached and delivered. Key impacts include:

- Accessibility and flexibility. LMS enable learners to access course materials and participate in learning activities at their convenience, thereby accommodating diverse schedules and learning paces.
- Enhanced engagement. Interactive features and multimedia content within LMS contribute to a more engaging and immersive learning experience.
- Data-driven insights. The analytical capabilities of LMS provide educators with valuable insights into learner behaviors and outcomes, informing evidence-based instructional strategies.
- Scalability. LMS facilitate the delivery of education to a large number of learners across different geographical locations, supporting the democratization of education.

Popular LMS Platforms

The most popular Learning Management Systems (LMS) platforms widely used in educational institutions and corporate training environments include:

1. **Moodle**

Open-source: Free to use and customizable, making it a popular choice for educational institutions.

Features: Supports course creation, assignments, grading, forums, and multimedia content.

2. **Blackboard Learn**

Widely Used: Popular in higher education institutions.

Features: Comprehensive tools for course management, assessments, analytics, and mobile access.

3. Canvas by Instructure

User-Friendly: Known for its intuitive interface and ease of use.

Features: Course management, grading, communication tools, and integration with various third-party apps.

4. Google Classroom

Integration: Integrates seamlessly with other Google services.

Features: Streamlined assignment management, communication tools, and collaboration features.

5. Schoology Learning

K-12 Focus: Widely used in primary and secondary education.

Features: Course management, assessments, analytics, and social learning tools.

6. TalentLMS

Corporate Training: Popular in corporate settings for training and development.

Features: Course creation, progress tracking, assessments, and certifications.

7. Edmodo

Social Learning: Combines learning management with social networking features.

Features: Assignments, quizzes, communication tools, and parent-teacher collaboration.

8. D2L Brightspace

Versatile: Suitable for both academic and corporate environments.

Features: Course management, analytics, adaptive learning, and mobile access.

9. SAP Litmos

Enterprise Focus: Designed for large organizations.

Features: Course creation, reporting, compliance tracking, and mobile learning.

10. Adobe Learning Manager

Multimedia Integration: Strong focus on multimedia content and interactive learning.

Features: Course management, video conferencing, gamification, and mobile access.

Each of these platforms has its unique strengths and is tailored to meet different educational and training needs. The choice of an LMS often depends on specific requirements such as ease of use, customization options, integration capabilities, and cost.

Challenges and Considerations

Learning Management Systems are becoming indispensable instruments in the fields of education, corporate training, and skill development in the current digital era. But while these platforms have many advantages, they are not without challenges.

Here are the top 10 challenges you might face when managing an LMS:

1. **Intuitive User Experience (UX)**

Challenge: Not all LMS platforms are user-friendly. A complex interface can deter users, impacting learning or training outcomes.

Solution: Regularly collect feedback from users and make necessary adjustments. Choose an LMS with an intuitive interface or invest in customizing it to suit your audience's needs

2. **Integrating with Other Systems**

Challenge: An LMS might need to be integrated with other tools such as HR systems, email platforms, or third-party apps. Integration challenges can arise, leading to disrupted functionality. Solution: Opt for LMS platforms that support API integrations or built-in connectors for popular tools. Regularly update and test integrations for smooth operations.

3. Keeping Content Relevant and Updated

Challenge: Over time, content can become outdated or irrelevant, diminishing the learning experiences' value.

Solution: Periodically review and update courses. Encourage content creators to remain updated with the latest trends in their domain. Create a content calendar or schedule for regular reviews

4. Scalability Concerns

Challenge: As organizations grow, the LMS might not be equipped to handle an increased number of users, leading to performance issues.

Solution: Choose an LMS that offers scalability features. Cloud-based LMS platforms often provide the flexibility to scale according to changing needs

5. Technical Glitches and Downtimes

Challenge: Technical issues can lead to downtimes, impacting the learning process. Solution: Regular maintenance, timely updates, and having a dedicated technical support team can mitigate these issues. Also, select an LMS with a good track record of uptime.

6. Data Security and Privacy

Challenge: With rising cyber threats, ensuring the security of users' data and content becomes a priority.

Solution: Opt for platforms with strong encryption, two-factor authentication, and regular security audits. Stay updated with global data protection regulations and ensure compliance.

7. Tracking and Reporting Limitations

Challenge: If the LMS doesn't offer comprehensive tracking and reporting features, assessing the effectiveness of the training becomes difficult.

Solution: Choose an LMS that provides detailed analytics on user engagement, course completion rates, and feedback. Utilize third-party analytics tools if needed.

8. Mobile Accessibility

Challenge: With the rise of mobile learning, an LMS that isn't mobile-responsive can hinder user engagement.

Solution: Ensure the LMS supports mobile accessibility. Offer mobile apps or ensure web responsiveness to cater to users on the go.

9. Customization Restrictions

Challenge: Every organization has unique needs. An LMS that doesn't allow customization might not align with specific requirements.
Solution: Opt for platforms that support modular designs and allow third-party integrations. This enables the addition of custom features and functionalities.

10. Cost Management

Challenge: Maintaining an LMS can become expensive, especially with growing needs.
Solution: Analyze the return on investment (ROI) regularly. Opt for subscription-based models or open-source platforms, which might be more cost-effective in the long run (Next Generation eDucation, 2023).

Thus, despite their numerous advantages, the implementation and utilization of LMS are not without challenges. Issues such as digital divide, user resistance, data privacy, and the need for ongoing technical support must be addressed to maximize the effectiveness of LMS. Furthermore, the quality of instructional design and the pedagogical approaches employed within LMS are critical determinants of their success.

Conclusion

As educational institutions and organizations continue to embrace digital transformation, Learning Management Systems (LMS) are poised to play an increasingly central role in the future of education. This Lesson provided an overview of LMS, exploring their historical development, key functionalities, impacts on educational practices, and the challenges associated with their use. By understanding the intricacies of LMS, educators and administrators can better leverage these systems to create more effective, inclusive, and engaging learning environments.

This Lesson explored various aspects of Learning Management Systems, laying the groundwork for further discussions on specific LMS platforms, implementation strategies, and best practices.

The Lesson also underscored the importance of addressing the challenges associated with LMS use. These challenges, ranging from technical issues to user resistance, must be thoughtfully managed to fully realize the potential of LMS. Through a detailed analysis of these challenges and potential solutions, educators and administrators can develop strategies to overcome obstacles and enhance the efficacy of LMS.

In conclusion, the evolving landscape of education necessitates a deep understanding of Learning Management Systems. By examining their development, functionality, and implementation, this Lesson aims to provide a foundation to navigate the digital transformation of education with confidence and foresight.

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Lesson 2.3.2. Social Media for Education

Learning Outcomes

By the end of this lesson, learners will be able to:

- Understand the role and impact of social media in digital education.
- Identify popular social media platforms used in educational settings and their specific applications.
- Analyse the benefits and challenges associated with integrating social media into educational practices.
- Discuss ethical considerations in using social media for educational purposes.
- Develop a strategic plan for incorporating social media into educational environments effectively and ethically.

Lesson content

Introduction

Social media encompasses digital technologies that enable the sharing of ideas and information through virtual networks and communities. It includes platforms like Facebook, Twitter, Instagram, LinkedIn, and many others. These platforms allow users to post text, images, videos, and other multimedia content, facilitating communication and interaction on a global scale. The rapid evolution and widespread adoption of social media have profoundly impacted various aspects of society, including education.

VIDEO 2.3.3. Social Media for Higher Education [*duration 2:11 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88874/mod_book/chapter/2683/Social%20Media%20for%20HE.mp4

VIDEO 2.3.4. Using social media in education [*duration 2:35 minutes*]**:** https://www.youtube.com/watch?v=TtEKXoGhZsI&t=7s

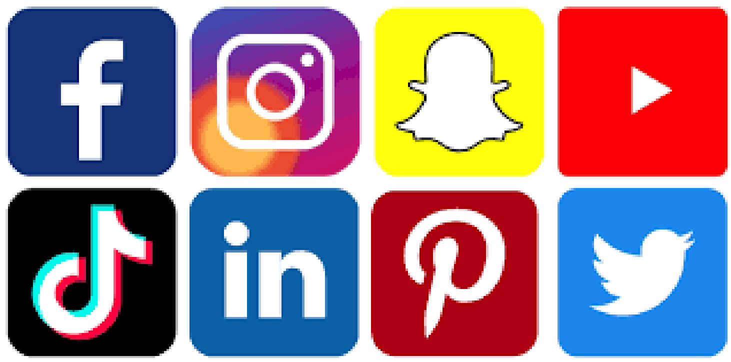
The Role of Social Media in Modern Education

In modern education, social media serves several pivotal roles:

1. Enhanced communication. Social media platforms facilitate communication between educators and students, breaking down barriers of time and location. This accessibility supports more dynamic and continuous interaction, fostering a more engaged learning environment.
2. Collaborative learning. Social media tools support collaborative learning through forums, discussion groups, and virtual study groups. These platforms enable students to share resources, discuss ideas, and work together on projects, enhancing the overall learning experience.
3. Access to resources. The wealth of information available on social media platforms provides students and educators with access to a wide range of resources, including academic articles, instructional videos, and expert opinions. This easy access to information supports self-directed learning and the discovery of diverse perspectives.
4. Professional development. For educators, social media offers opportunities for professional development through online communities, webinars, and social learning networks. These resources help teachers stay updated with the latest educational trends, methodologies, and technologies.

5. Student engagement. Integrating social media into the classroom can increase student engagement by leveraging familiar technologies to create interactive and enjoyable learning experiences. Platforms like YouTube, for instance, can be used to share educational videos, while Twitter can facilitate real-time discussions and debates.

Popular Social Media Platforms for Education



Several social media platforms are commonly used in educational settings to facilitate communication, collaboration, and learning. Below are some of the most popular ones:

1. **Facebook**:
    - Groups: Facebook Groups can be used to create communities for classes, study groups, or special interest groups. They provide a space for sharing resources, discussions, and announcements.
    - Pages: Educators and institutions can create Pages to share information, updates, and educational content with a wider audience.

2. **Twitter:**
    - Hashtags: Hashtags like #edchat and #edtech can be used to find and participate in educational conversations. They help in connecting with a broader educational community.
    - Lists: Twitter Lists can be curated to follow specific educators, experts, or organizations, providing a tailored feed of relevant educational content.

3. **YouTube:**
    - Channels: Educators can create channels to upload and organize video content, such as lectures, tutorials, and explainer videos.
    - Playlists: Playlists can be used to curate and categorize educational videos, making it easier for students to follow a series of related content.

4. **LinkedIn:**

- Professional networking: LinkedIn is valuable for connecting with other educators, professionals, and organizations. It supports professional development and networking.
- Groups: LinkedIn Groups provide a platform for discussions and sharing resources among professionals with similar interests.

5. **Instagram:**

- Visual content: Instagram can be used to share visual content related to educational activities, events, and achievements.
- Stories and IGTV: These features allow for sharing short updates and longer video content, which can be educational or informational.

6. **Edmodo:**

- Classroom management: Edmodo is designed specifically for educational purposes, providing tools for assignments, quizzes, and discussions within a secure environment.
- Parent communication: It facilitates communication between teachers, students, and parents, helping to keep everyone informed and engaged.

7. **Pinterest:**

- Boards: Pinterest Boards can be used to collect and organize educational resources, lesson plans, and ideas.
- Pins: Educators can share and discover educational content through Pins, which link to resources and articles.

8. **WhatsApp:**

- Groups: WhatsApp Groups allow for quick and easy communication among students and educators. It can be used for sharing updates, resources, and conducting discussions.
- Broadcast lists: Educators can send announcements to multiple students without creating a group, maintaining privacy and reducing unnecessary notifications.

9. **Reddit:**

- Subreddits: Subreddits like r/education and r/teachers provide forums for educators to share resources, seek advice, and discuss educational topics.
- AMAs: "Ask Me Anything" sessions with experts can provide valuable insights and knowledge on various subjects.

10. **TikTok:**

- Short educational videos: TikTok can be used to create short, engaging educational videos on various topics. Educators can leverage trends to make learning fun and relatable.
- Challenges and hashtags: Educational challenges and hashtags help in spreading knowledge and engaging students in creative ways.

These platforms offer diverse tools and features that can enhance the educational experience. When used effectively, they can support communication, collaboration, and access to a wealth of resources, making learning more interactive and engaging. However, it's essential to consider the privacy and security implications and ensure that students are guided in using these platforms responsibly.

Benefits and Challenges

Benefits:

1. Increased accessibility. Social media makes education more accessible by providing learning materials and opportunities to individuals regardless of their geographical location.
2. Enhanced collaboration.The collaborative nature of social media encourages teamwork and peer learning, which are essential skills in the modern workforce.
3. Real-world learning. Social media can bridge the gap between theoretical knowledge and real-world application by connecting students with industry professionals and current events.

4. Immediate feedback. Platforms enable instant feedback on assignments and discussions, which can accelerate the learning process and help students quickly identify areas for improvement.

Challenges:

1. Distraction. The use of social media can lead to distractions, diverting students' attention from their studies to non-educational content.
2. Information overload. The vast amount of information available on social media can be overwhelming, making it challenging for students to discern credible sources from unreliable ones.
3. Privacy concerns. The use of social media in education raises privacy issues, as students' personal information can be exposed to a broader audience.
4. Digital divide. Not all students have equal access to the necessary technology and internet connectivity, potentially exacerbating educational inequalities.

Ethical Considerations

The integration of social media in education brings forth several ethical considerations:

1. **Privacy and data protection.** Educators must ensure that students' personal information is protected and that privacy settings are appropriately managed. This includes understanding the terms of service of various platforms and educating students about data security.
2. **Digital citizenship.** Teaching students about responsible and ethical behavior online is crucial. This includes understanding the implications of their digital footprint, respecting intellectual property, and engaging in positive online interactions.
3. **Equity and inclusion.** Efforts should be made to ensure that all students have equal access to the benefits of social media in education. This might involve providing resources or support for students who lack access to necessary technology.

4. **Academic integrity.** The ease of sharing information on social media can lead to issues of plagiarism and academic dishonesty. Educators need to emphasize the importance of original work and proper citation practices.
5. **Mental health.** The impact of social media on mental health is a growing concern. The pressure to present a certain image and the potential for cyberbullying can affect students' well-being. Schools should provide support and resources to address these issues.

Creating a Social Media Strategy for Education

A well-crafted social media strategy can significantly enhance the educational experience by fostering communication, collaboration, and engagement. Here is a step-by-step guide to creating an effective social media strategy for education:

1. Define your objectives

Start by identifying the primary goals of your social media strategy. Common objectives in educational settings include:

- Enhancing communication between students, educators, and parents.
- Promoting collaborative learning and peer interaction.
- Increasing access to educational resources and information.
- Building a supportive online community.
- Enhancing the institution's visibility and reputation.

2. Identify your audience

Understand who your target audience is. In education, this could include:

- Students at various educational levels.
- Educators and academic staff.
- Parents and guardians.
- Alumni and prospective students.
- Other stakeholders such as industry partners.

3. Choose the right platforms

Select social media platforms that align with your objectives and audience. For instance:

- Facebook: for creating groups, events, and sharing updates.
- Twitter: for real-time communication and sharing news.
- Instagram: for sharing visual content and stories.
- LinkedIn: for professional networking and sharing academic achievements.
- YouTube: for uploading and organizing educational videos.

4. Develop a content plan

Create a content plan that outlines the type of content you will share, the frequency of posts, and the platforms you will use. Consider the following types of content:

- Announcements and Updates: Important dates, events, and news.
- Educational Resources: Articles, videos, tutorials, and infographics.
- Engagement Posts: Polls, questions, and interactive content to engage your audience.
- Showcasing Achievements: Highlighting student and faculty achievements and milestones.

5. Establish a posting schedule

Consistency is key to maintaining an active and engaging social media presence. Develop a posting schedule that outlines when and how often you will post content. Use tools like social media calendars to plan and organize your posts.

6. Encourage participation and interaction

Promote active participation by encouraging students and educators to share their own content, comment on posts, and engage in discussions. This can be achieved by:

- Creating hashtag campaigns.
- Hosting live Q&A sessions or webinars.
- Organizing virtual events and challenges.

7. Monitor and analyze performance

Regularly monitor your social media performance to understand what works and what doesn't. Use analytics tools provided by the platforms to track metrics such as:

- Engagement rates (likes, comments, shares).
- Reach and impressions.
- Follower growth.
- Click-through rates on shared links.

Use this data to refine your strategy and make informed decisions about future content and activities.

8. Ensure privacy and security

Maintaining the privacy and security of your audience is crucial. Educate students and staff about best practices for online safety and data protection. Ensure that all interactions adhere to institutional policies and legal regulations regarding privacy.

9. Train educators and staff

Provide training for educators and staff on how to effectively use social media for educational purposes. This includes:

- Best practices for content creation and engagement.
- Understanding platform-specific features and tools.
- Managing online interactions and addressing issues such as cyberbullying.

10. Foster a positive online community

Encourage a positive and supportive online community by promoting respectful interactions and addressing negative behavior promptly. Establish clear guidelines for behavior and communicate these to your audience.

Creating a social media strategy for education involves careful planning and continuous monitoring. By defining clear objectives, understanding your audience, and consistently delivering valuable content, you can leverage social media to enhance the educational experience and build a strong online community.

Remember to prioritize privacy and security, and provide ongoing support and training to educators and staff to ensure the success of your strategy.

Conclusions

Social media has the potential to significantly enhance modern education by improving communication, collaboration, and access to resources. However, it also presents several challenges and ethical considerations that must be carefully managed. By addressing these issues, educators can leverage social media to create more dynamic, inclusive, and effective learning environments.

Improving communication between educators and students, social media platforms facilitate immediate feedback and foster a sense of community. Collaborative tools allow students to engage with peers and educators beyond traditional classroom boundaries, enhancing teamwork and critical thinking skills. Additionally, the vast array of resources available on social media provides learners with diverse perspectives and materials, enriching the educational experience.

However, the integration of social media in education is not without its challenges. Privacy concerns, the potential for cyberbullying, and the risk of distraction are significant issues that need careful consideration. Furthermore, the digital divide can exacerbate inequalities, as not all students have equal access to technology and the internet.

Ethical considerations also play a crucial role. Ensuring that content shared on social media adheres to academic integrity, protecting students' data, and promoting respectful online behavior are essential to creating a safe and productive learning environment.

To fully harness the benefits of social media in education, a balanced approach is necessary. Educators should receive training on best practices for incorporating social media into their teaching strategies while maintaining a critical awareness of its limitations and potential pitfalls. Institutions should implement robust policies to safeguard against misuse and ensure equitable access for all students.

In conclusion, social media holds great promise for transforming education by enhancing communication, collaboration, and access to resources. With careful management of the associated challenges and ethical considerations, it can become a powerful tool for creating more dynamic, inclusive, and effective learning environments. By embracing these opportunities and addressing the potential drawbacks, educators can foster a more connected and enriched educational landscape.

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Lesson 2.3.3. Collaborative Tools and Applications

Learning Outcomes

By the end of this lesson, learners will be able to:

- Understand the concept of collaboration.
- Distinguish between types of collaborative work.
- Identify and utilize collaborative tools.
- Engage students and build academic communities.

Lesson content

Introduction

Definition Collaboration

Types of Collaborative Work

Networking and Collaboration Tools

Engaging Students and Building Community

Conclusion

Sources

Introduction

The advent of digital technology has revolutionized various sectors, including education. Collaborative tools and applications have emerged as pivotal elements in modern educational environments, facilitating enhanced interaction, engagement, and knowledge sharing among students and educators. These tools encompass a wide range of platforms, including cloud-based services, social media, and specialized educational software, all designed to foster collaborative learning experiences.

In contemporary education, collaboration extends beyond the traditional classroom setting, enabling students to engage in real-time discussions, joint projects, and shared resources regardless of geographical constraints. This Lesson delves into the diverse array of collaborative tools available, examining their functionalities, advantages, and potential challenges. By exploring case studies and current research, we aim to provide an understanding of how these tools can be effectively integrated into educational practices to enhance learning outcomes and promote a more interactive and inclusive educational experience.

VIDEO 2.3.5. Collaborative Tools [*duration 2:13 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88875/mod_book/chapter/2691/Collaborative%20tools.mp4

Definition of Collaboration

The concept of collaboration lacks a universally accepted definition, being a construct that encompasses a myriad of definitions and frameworks. The characterization of collaboration takes different forms in different disciplines, including psychology, sociology, education, public administration, management, social work and health sciences (Virkus, 2007).

Etymologically, the word collaboration derives from the Latin verb 'collaborare', meaning to labor together (Merriam-Webster, n.d.). The Cambridge English Dictionary defines collaborative working as "the act of two or more people or organizations working together for a particular purpose" (The Cambridge English Dictionary, 2023). Roschelle and Teasley (1995, p. 70) define collaboration as "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem". Mattessich and Monsey (1992) propose the following definition: "Collaboration is a mutually beneficial and well-defined relationship entered into by two or more organizations to achieve common goals". Bedwell et al. (2012) define collaboration "as an evolving process whereby two or more social entities actively and reciprocally engage in joint activities aimed at achieving at least one shared goal". In their conception, the collaborating entities are brought together by their different skills or resources with the aim of jointly tackling a task of common interest (Virkus, 2024).

Thus, collaboration is mostly defined as the activity, relationship, structure, methodology, process or practice of two or more entities working together to achieve a common goal (Virkus, 2007). Collaboration involves exchanging ideas, sharing resources and expertise. It can take place at different levels such as within teams, across teams, or encompassing entire organizations. Collaboration takes place in a variety of contexts, from physical workspaces and virtual team environments to online communities. In addition, cross-border collaboration is a form of collective work that transcends traditional organizational boundaries. It is a practice that transcends the boundaries of units, disciplines, geographical locations, time considerations and hierarchical structures (Virkus, 2024).

However, the concept of collaboration is often used interchangeably with cooperation, coordination, teamwork and partnership (Virkus, 2007).

Types of Collaborative Work

Synchronous vs Asynchronous Collaboration

Synchronous collaboration: Synchronous collaboration refers to real-time communication and interaction among team members. This mode of collaboration requires participants to be present at the same time, engaging simultaneously in activities or discussions. Common examples include:

- Meetings: Physical or virtual gatherings where participants discuss issues, brainstorm ideas, and make decisions collectively.
- Video conferencing: Platforms like Zoom or Microsoft Teams allow team members to hold live discussions, presentations, and collaborative work sessions.
- Live Chat: Instant messaging tools like Slack or Microsoft Teams where team members can quickly exchange information and ideas.

Advantages of synchronous collaboration include immediate feedback, dynamic interaction, and the ability to quickly resolve issues. However, it can be challenging to coordinate schedules, especially for distributed teams across different time zones.

Asynchronous collaboration: Asynchronous collaboration involves communication and interaction that do not require participants to be present at the same time. This allows team members to contribute at their convenience. Examples include:

- Email: Team members send messages and documents, and recipients respond at their own pace.
- Collaboration platforms: Tools like Google Drive, Trello, or Asana where team members can update and access shared documents, tasks, and projects independently.
- Discussion forums: Online forums or boards where ideas and feedback can be posted and reviewed asynchronously.

The benefits of asynchronous collaboration include flexibility, accommodation of different time zones, and the ability to reflect and respond thoughtfully. However, it may lead to delays in decision-making and slower feedback loops.

Team Collaboration vs Project Collaboration

Team collaboration: Team collaboration refers to the ongoing process where a group of individuals work together towards common objectives, often within the context of an organization. This collaboration is typically continuous and focuses on achieving long-term goals. Characteristics include:

- Shared goals: Team members work together to achieve shared objectives, such as improving a product or increasing customer satisfaction.
- Role diversity: Teams often consist of members with diverse roles and expertise, contributing their unique skills to the collective effort.
- Interpersonal relationships: Strong interpersonal relationships and effective communication are critical for successful team collaboration.

Team collaboration emphasizes a cohesive and sustained effort, leveraging the strengths of each member to improve overall performance and outcomes.

Project collaboration: Project collaboration is more focused and time-bound, involving individuals or groups working together to complete specific projects. Each project has defined goals, deliverables, and timelines. Key features include:

- Specific objectives: Projects have clear, well-defined objectives and outcomes, such as launching a new product or implementing a new system.
- Temporary teams: Project teams may be formed temporarily, drawing members from various departments or organizations to leverage their expertise for the project's duration.
- Milestones and deadlines: Projects are structured with milestones and deadlines to ensure timely completion and measure progress.

Project collaboration centers on achieving specific, short-term goals within a set timeframe, often requiring focused and intensive efforts from the team members involved.

Networking and Collaboration Tools

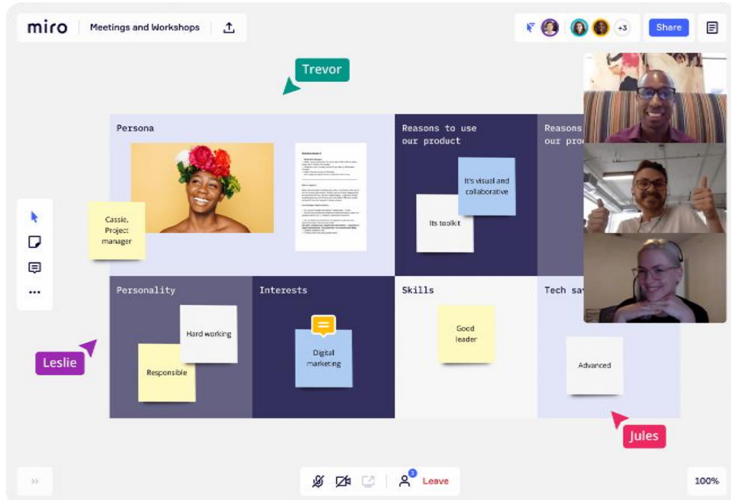
There are a variety of free and commercial collaboration and networking tools/platforms that support learning and teaching and allow teachers to share materials with their learners and work on them together in real time, or asynchronously. This can enable strengthening of the teacher- learner online relationship, which is particularly valuable in the early stages of a course.

In addition, a range of collaborative networking tools can be used to foster group working and a sense of community between learners on an online course. Instant messaging apps can foster backchannels. Activities using Twitter or Pinterest to search for information, or using Diigo to gather together relevant internet bookmarks, can help bring an online group together with a shared objective, as well as exposing that group to a wider community in a relevant subject area (OU, 2017).

VIDEO 2.3.6. Best Online Collaboration Tools [*duration 6:16 minutes*]: https://www.youtube.com/watch?v=UmQSZtWGntg&t=1s

Networking and Collaboration Tools

1. Miro



Miro is a whiteboard platform that is great for collaborative learning. This platform is excellent for structuring ideas while encouraging students and teams to collaborate. Thanks to its intuitive and comprehendible design, teams can engage in brainstorming, plan activities, give/ask for feedback and suggestions, present different concepts, etc. In addition, the platform comes with a chat, comment, and video section. Miro is free for personal use only. The paid version costs $8 per user, monthly.

You can find out more about this platform in the following video

VIDEO 2.3.7. Getting Started with Miro [*duration 27:47 minutes*]: https://www.youtube.com/watch?v=pULLAEmhSho&t=4s

2. Teachfloor

Teachfloor is a cohort-based collaborative learning platform that allows to make the learning experience engaging, collaborative, and interactive. Enables creating, managing, and selling online cohort-based courses. Combine synchronous and asynchronous communication. Offers a 15-day trial period, after which you get to choose between the business and the pro tier. The pro tier (up to 100 students) costs $99 per month, whereas you get a custom quote for the business tier.

teachfloor

Benefits:

- Create cohort-based learning in minute — not days.

- Create a collaborative environment using peer learning.
- Manage communities to encourage valuable discussions and connections.
- Build an entire academy under your brand
- Use Zoom to run, sync, and automate classes.

Cohort-based learning describes a learning style where a group of students (a 'cohort') take a series of classes together as a group. Students have the same learning schedules and deadlines as opposed to working at their own pace.

3. Nearpod

Nearpod is considered one of the best collaborative learning tools for interactive presentations and assessments. Thanks to its intuitive interface, it is straightforward to create lessons and videos. It is super-easy to upload learning materials from places such as YouTube, PowerPoint, and Google Slides. Starting an interactive discussion is another thing designed to be easily accessible. One just needs to click on some lesson slides, add a topic to that particular slide, and learners can respond to it the moment they reach it. Learners can give a video, audio, or textual response. Users can choose between three tiers: Silver (free), Golden ($120 per year), and Platinum ($349 per year).

You can find out more about this platform in the following video Nearpod for Teachers.

4. Zoom

Zoom is a synchronous virtual meeting tool supporting communication and collaboration using video, audio, screen-sharing and text chat, and include options to split groups into breakout rooms, audio and camera control, the ability to record meetings, virtual background, gallery and portrait views, and so on. Can host up to 500 people at one video meeting. Unlimited chat time is available only for paid accounts. **Zoom Webinars** are useful for more one-way communication with a large size group (up to 500). Options for participants to communicate are restricted, making it more suitable for announcements and general information to a large group, rather than for two-way or small-scale collaboration. In addition to its free tier, Zoom offers three more premium tiers: pro, business, and enterprise. The pro tier costs $14 per host monthly, whereas both the business and enterprise tiers cost $19 per host monthly.

You can find out more about this platform in the following video Zoom tutorial 2022.

5. Microsoft Teams

Microsoft Teams is a unified collaboration and communications platform that merges chat with video meetings, file storage, attachments and app integration. It supports synchronous and asynchronous activity via sharing of files, a number of different communication modes and a rich suite of integrated tools.

One of the standout advantages of Microsoft Teams lies in its seamless integration with the broader Office 365 ecosystem. This means users can effortlessly access and leverage familiar tools like Word, Excel, and PowerPoint within the Teams interface, consolidating their workflow and minimizing disruptions. Furthermore, the platform offers ample cloud storage per user, ensuring that teams have the necessary resources to store and share files without constraints. This not only promotes collaboration but also facilitates efficient information management and retrieval.

Despite its strengths, Microsoft Teams does present some challenges, particularly for new users. The interface, with its wealth of features and functionalities, may initially appear complex, requiring a learning curve for full mastery. Additionally, setting up the platform and navigating its various components may pose initial hurdles for those unfamiliar with its workings.

To support users in overcoming these challenges and maximizing their utilisation of Microsoft Teams, a tutorial video is available. This resource offers step-by-step guidance on getting started with the platform, exploring its features, and harnessing its full potential for collaboration and communication.

In essence, Microsoft Teams represents a powerful tool for modern teams seeking to collaborate effectively in today's fast-paced digital environment. With its comprehensive suite of features, seamless integration, and user-friendly interface, it empowers teams to connect, communicate, and collaborate with ease, driving productivity and innovation across organizations.

You can find out more about this platform in the following video Microsoft Teams Tutorial.

6. Slack

Slack is a single platform that enables teams to collaborate on complex projects. It offers a wide range of communication and productivity tools such as real-time messaging (chat and calls), integration with apps and bots, searchable conversations, searchable records, etc. As a result, every team member is in the loop and is always up-to-date with things. In addition to the free tier, Slack offers three more premium tiers: standard, plus, and enterprise grid. The standard tier costs $6.67 per user monthly, the plus tier costs $12.50, whereas you can get a custom quote for the enterprise grid.

You can find out more about this platform in the following video Slack Review.

7. Google Docs

Google Docs allows multiple people to edit the same file at same time, leave comments, and see changes made by every participant (revision history). All you have to do is invite team members to work on a file in Google docs. With that, all participants have a central place to store and share information, take notes, and just seamlessly collaborate and have access to the information they need to get work done.

The advantages of utilising cloud-based systems are evident. Firstly, there's the convenience factor: with no installations necessary, users can swiftly access the platform without the hassle of setting up software. Moreover, the seamless integration with Google Drive ensures that all modifications made to documents are instantly preserved, mitigating the risk of data loss. Another notable perk is the real-time visibility of changes, enabling multiple collaborators to engage simultaneously and witness edits unfold dynamically.

However, despite these merits, it's essential to acknowledge the limitations inherent in such systems. One notable drawback is the comparatively restricted feature set when juxtaposed with robust word processing software like Microsoft Word. While cloud-based platforms excel in accessibility and collaboration, they may lack the extensive functionalities and customisation options found in traditional applications like Word. Thus, users must weigh the benefits of convenience and real-time collaboration against the potential trade-offs in functionality and versatility.

You can find out more about this platform in the following video How to Use Google Docs.

8. Google Workspace

Google Workspace (formerly known as Google Apps and later G Suite) is a collection of cloud computing, productivity and collaboration tools, software and products developed and marketed by Google. Google Workspace consists of Gmail, Contacts, Calendar, Meet and Chat for communication; Currents for employee engagement; Drive for storage; and the Google Docs suite for content creation. Depending on edition Google Workspace may also include the digital interactive whiteboard Jamboard and an option to purchase such add-ons as the telephony service Voice. The education edition adds a learning platform Google Classroom and today has the name Workspace for Education.

You can find out more about this platform in the following video What is Google Workspace?

9. Perusall

Perusall is a social reading platform integrated into Moodle that allows students (and teaching staff) to digitally annotate readings and videos collaboratively (with text, links, and embedded content), and respond to each other's comments and questions. The Perusall platform is free for students, instructors, and educational institutions. Based on extensive (patent-pending) data analytics, behavioural science, and educational research. Developed at Harvard by Gary King, Brian Lukoff, Eric Mazur, Kelly Miller.

You can find out more about this platform in the following video Introduction to Perusall.

Engaging Students and Building Community

The contemporary educational landscape is marked by rapid technological advancements, diverse student populations, and evolving pedagogical approaches. Central to navigating these dynamics is the imperative of engaging students and building robust academic communities. This chapter delves into strategies for fostering student engagement and community building within academic settings, underscoring their significance for educational success.

The Importance of Student Engagement

Student engagement refers to the degree of attention, curiosity, interest, optimism, and passion students show when they are learning or being taught. It extends to their level of motivation to learn and progress in their education. High levels of engagement are linked to improved learning outcomes, higher retention rates, and greater student satisfaction.

1) Cognitive Engagement: Involves intellectual investment and effort in learning, characterized by a willingness to tackle complex problems and understand intricate concepts. This can be enhanced through stimulating curricula, interactive lectures, and challenging assignments.

2) Emotional Engagement: Pertains to students' emotional responses to their learning experiences, including feelings of interest, enjoyment, and a sense of belonging. Emotional engagement can be fostered through supportive teacher-student relationships and a positive classroom climate.

3) Behavioral Engagement: Relates to students' participation in academic, social, and extracurricular activities. Encouraging active participation in class, promoting involvement in student organizations, and facilitating attendance at academic events can boost behavioral engagement.

1. Building a Learning Community

A learning community is a group of people who share common academic goals and attitudes, and work collaboratively to achieve them. Building a strong community within academic settings enhances social support, shared learning experiences, and a sense of belonging, all of which contribute to student success.

1) Inclusive Environment: Creating an inclusive environment where all students feel valued and respected is crucial. This involves recognizing and accommodating diverse backgrounds, perspectives, and learning styles.

2) Collaborative Learning: Encouraging collaborative learning through group projects, peer-to-peer learning, and discussion forums helps students learn from one another and build strong academic and social connections.
3) Faculty-Student Interaction: Meaningful interactions between faculty and students foster a supportive learning environment. Office hours, mentorship programs, and informal interactions can significantly contribute to building strong relationships.
4) Extracurricular Activities: Participation in extracurricular activities such as clubs, sports, and cultural events enhances community spirit and provides opportunities for personal growth and socialization.

2. Strategies for Engaging Students and Building Community

1) Active Learning Techniques: Implementing active learning techniques such as problem-based learning, case studies, and interactive simulations can make learning more engaging and participatory.
2) Technology Integration: Utilizing technology to create interactive and personalized learning experiences can enhance student engagement. Learning management systems, online discussion boards, and virtual classrooms offer platforms for continuous interaction and feedback.
3) Feedback and Assessment: Regular feedback and assessment help students understand their progress and areas for improvement. Constructive feedback motivates students and keeps them engaged in their learning journey.
4) Professional Development for Educators: Providing professional development opportunities for educators to learn new pedagogical strategies and technologies ensures they are well-equipped to engage students effectively.
5) Community Building Activities: Organizing community-building activities such as orientation programs, team-building exercises, and social events helps students develop a sense of belonging and camaraderie.

Examples

- Flipped Classroom Model: The flipped classroom model, where students review content at home and engage in interactive activities in class, has shown significant improvements in student engagement and academic performance.

- Learning Communities in Higher Education: Institutions that have implemented learning communities, where students take courses together and participate in shared activities, report higher retention rates and enhanced student satisfaction.
- Service Learning Projects: Integrating service-learning projects into the curriculum connects academic content with real-world applications, fostering civic responsibility and community engagement among students.

Engaging students and building a cohesive academic community are fundamental to achieving educational excellence. Through intentional strategies that promote cognitive, emotional, and behavioral engagement, and by fostering a supportive and inclusive learning environment, educators can enhance student learning experiences and outcomes. As the educational landscape continues to evolve, the commitment to these principles will remain paramount in shaping the future of education.

Conclusion

In the modern educational landscape, the integration of collaborative tools and applications plays a pivotal role in enhancing student engagement and building vibrant academic communities. These technologies facilitate interactive learning experiences, foster peer-to-peer collaboration, and enable seamless communication between students and educators.

Collaborative tools such as online discussion boards, shared digital workspaces, and real-time collaboration software (e.g., Google Workspace, Microsoft Teams) provide platforms for students to work together on projects, share resources, and offer feedback. These tools not only make learning more engaging but also help develop essential skills such as teamwork, communication, and critical thinking.

Furthermore, applications that support virtual classrooms and asynchronous learning (e.g., Zoom, Canvas, Moodle) allow for flexible and inclusive educational experiences. They enable students from diverse backgrounds and with varying schedules to participate fully in the learning process, thereby fostering a sense of community regardless of physical location.

By leveraging these collaborative tools and applications, educators can create dynamic and interactive learning environments that encourage active participation and collaboration. This, in turn, strengthens the academic community, enhances student learning outcomes, and prepares students for the collaborative nature of the modern workplace.

As we move forward, the continued adoption and innovation of collaborative technologies in education will be crucial. These tools not only support the pedagogical shift towards more interactive and student-centered learning but also play a key role in building cohesive and supportive educational communities. Embracing these advancements will ensure that education remains relevant, engaging, and effective in meeting the needs of all students.

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Self-Assessment Quiz

Test your knowledge by taking the **Self-Assessment Quiz** (https://open.ktu.edu/mod/quiz/view.php?id=17824) included in the 3 rd. Topic, "Digital Tools for Education" of the MOOC "Digital Education" (https://open.ktu.edu/course/view.php?id=194).

TOPIC 2.4. Assessment and Evaluation in Digital Education

Lesson 2.4.1. Types of Assessment in Online Learning

Learning Outcomes

By the end of this lesson, learners will be able to:

- Identify and distinguish between different types of assessments;
- Understand the importance of assessment in educational contexts;
- Design effective assessment tasks;
- Select appropriate assessment methods and tools for various educational contexts and learning objectives;
- Utilize digital assessment tools;

Lesson content

Introduction

Importance of Assessment

Diagnostic, Formative and Summative Assessment

Other Types of Assessment

Formats of Assessment in Online Learning Environment

Understanding Assessment Design

Selecting Assessment Methods

Designing Assessment Tasks

Digital Assessment Tools

Conclusion

Sources

Introduction

In both professional and educational contexts, assessment is essential. In addition to measuring learning and performance, it also offers feedback, guarantees accountability, directs decision-making, authenticates credentials, inspires, encourages equity, permits benchmarking, and strengthens self-control. Setting and attaining goals for both individuals and organisations, encouraging ongoing improvement, and upholding high standards all depend on effective evaluation procedures.

Assessment has long been recognised by learning theories as a key component of the learning cycle. But there are several facets to the idea of learning assessment. “Assessment is the systematic collection of information about student learning, using the time, knowledge, expertise, and resources available, in order to inform decisions that affect student learning,” according to Walvoord (2010), for instance (p. 2). According to Angelo and Cross (1993), assessment is an interactive process that takes place between teachers and students to determine how successfully the former are educating the latter. Faculty members utilise the data to modify the learning environment, and students can use it to help them develop better study and learning habits.

The traditional view of assessment defines its primary role as evaluating a student’s comprehension of factual knowledge, whereas a more contemporary definition sees assessment as activities designed primarily to foster student learning (Webber, 2012).

Even though the phrases assessment and evaluation are sometimes used synonymously, it is crucial to distinguish between the two. Angelo and Cross (1993) identified some significant distinctions between assessment and evaluation. They contend that evaluation is distinct from grading. Assessment is process-oriented, continuous, diagnostic, and aimed at finding areas that require improvement in teaching and learning. Evaluation, on the other hand, determines grades based on whole performance, which includes things like effort, good behaviour, and attendance. The evaluation is final; it assigns a subjective overall grade or score and assesses the calibre of the knowledge gained.

This Lesson will provide you a grasp of the different types of assessments and their importance, enabling you to assess and improve student learning outcomes in an efficient and effective manner. We just address the assessment of learning in this Lesson; institutional assessment, course or programme evaluation, or both are not included. Within that, we limit our conversation to constructivist theory as it relates to higher education.

Importance of Assessment

Assessments are crucial in education as they measure learners' progress and achievements. Designing effective assessments ensures accurate and reliable evaluation of knowledge and skills acquired by learners. Learning assessment holds significant importance in the educational landscape for several reasons, aligning with pedagogical goals, instructional effectiveness, and student outcomes.

VIDEO 2.4.1. Importance of Assessment [*duration 00:48 minutes, created by the course authors*]: https://open.ktu.edu/mod/book/view.php?id=17832&chapterid=2712#mod_book-chapter

Key points on the importance of assessments:

1) *Measuring learning outcomes.* Assessments provide data on whether students meet educational objectives, identifying their knowledge and skills.
2) *Informing instruction.* They highlight student strengths and weaknesses, helping educators adjust teaching methods and improve programs.
3) *Facilitating reflective practice.* Assessments help teachers evaluate their effectiveness and foster continuous improvement.
4) *Guiding student learning.* Feedback from assessments helps students understand their progress and areas for improvement.
5) *Encouraging motivation.* Regular assessments set goals, fostering a growth mindset and lifelong learning.
6) *Enhancing self-regulation.* Self-assessment promotes autonomy and personal responsibility in learning.
7) *Ensuring equity.* Assessments identify educational inequities, prompting supportive interventions.
8) *Guiding decision-making.* Data from assessments informs curriculum design, resource allocation, and policy development.
9) *Providing accountability.* Assessments ensure schools, teachers, and students meet educational standards.

10) *Credentialing.* They validate that individuals meet specific standards for degrees and professional licenses.
11) *Benchmarking.* Assessments allow comparisons across groups and time periods, driving improvements.
12) *Supporting research.* Assessment data provides insights for educational research and best practices.

Assessments enhance education by measuring learning, informing improvement, providing feedback, ensuring accountability, guiding decisions, validating credentials, motivating, promoting equity, allowing benchmarking, and enhancing self-regulation. Effective assessments are key to achieving educational goals and maintaining high standards.

Diagnostic, Formative and Summative Assessment

The typical types of assessments are **diagnostic, formative** and **summative assessment.** Each type of assessment serves a distinct purpose, from gauging initial knowledge and skills to monitoring ongoing progress and evaluating cumulative learning outcomes. Understanding the various forms of these assessments and their applications can help educators tailor their teaching strategies to better meet students' needs, thereby enhancing the overall educational experience.

Diagnostic Assessment

Diagnostic assessment can help identify students' current knowledge of a subject, their skill sets and capabilities, and to clarify misconceptions before teaching takes place. Knowing students' strengths and weaknesses can help better plan what to teach and how to teach it. Types of diagnostic assessment are: a) pre-tests (on content and abilities); b) self-assessments (identifying skills and competencies); c) discussion board responses (on content-specific prompts); and interviews (brief, private, 10-minute interview of each student).

VIDEO 2.4.2. Formative and summative assessment [*duration 01:06 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88879/mod_book/chapter/2711/FA.mp4

Formative Assessment

Formative assessment provides feedback and information during the instructional process, while learning is taking place, and while learning is occurring. Formative assessment measures student progress but it can also assess your own progress as an instructor. For example, when implementing a new activity in class, you can, through observation and/or surveying the students, determine whether or not the activity should be used again or modified. A primary focus of formative assessment is to identify areas that may need improvement. These assessments typically are not graded and act as a gauge to students' learning progress and to determine teaching effectiveness (implementing appropriate methods and activities). Types of formative assessment are: a) observations during in-class activities; students non-verbal feedback during lecture; b) homework exercises as review for exams and class discussions; c) reflections journals that are reviewed periodically during the semester; d) question and answer sessions, both formal - planned and informal – spontaneous; e) meetings between the instructor and student at various points in the semester; f) in-class activities where students informally present their results; and g) student feedback collected by periodically answering specific question about the instruction and their self-evaluation of performance and progress.

Summative Assessment

Summative assessment takes place after the learning has been completed and provides information and feedback that sums up the teaching and learning process. Typically, no more formal learning is taking place at this stage, other than incidental learning which might take place through the completion of projects and assignments. Rubrics, often developed around a set of standards or expectations, can be used for summative assessment. Rubrics can be given to students before they begin working on a particular project so they know what is expected of them (precisely what they have to do) for each of the criteria. Rubrics also can help you to be more objective when deriving a final, summative grade by following the same criteria students used to complete the project.

Grades are usually an outcome of summative assessment: they indicate whether the student has an acceptable level of knowledge-gain - is the student able to effectively progress to the next part of the class? To the next course in the curriculum? To the next level of academic standing? Types of summative assessment are: a) examinations (major, high-stakes exams); b) final examination (a truly summative assessment); c) term papers (drafts submitted throughout the semester would be a formative assessment); d) projects (project phases submitted at various completion points could be formatively assessed); e) portfolios (could also be assessed during its development as a formative assessment); f) performances; g) student evaluation of the course (teaching effectiveness); and h) instructor self-evaluation.

Assessment measures if and how students are learning and if the teaching methods are effectively relaying the intended messages. Hanna and Dettmer (2004) suggest that you should strive to develop a range of assessments strategies that match all aspects of their instructional plans. Instead of trying to differentiate between formative and summative assessments it may be more beneficial to begin planning assessment strategies to match instructional goals and objectives at the beginning of the semester and implement them throughout the entire instructional experience. The selection of appropriate assessments should also match course and program objectives necessary for accreditation requirements

Other Types of Assessment

As an instructional designer, it is crucial to understand the various types of assessments available and their appropriate uses. By using different assessment methods, educators can gather a well-rounded picture of students' knowledge, skills, and abilities. In this topic, we will explore several common types of assessments and discuss their respective uses and benefits.

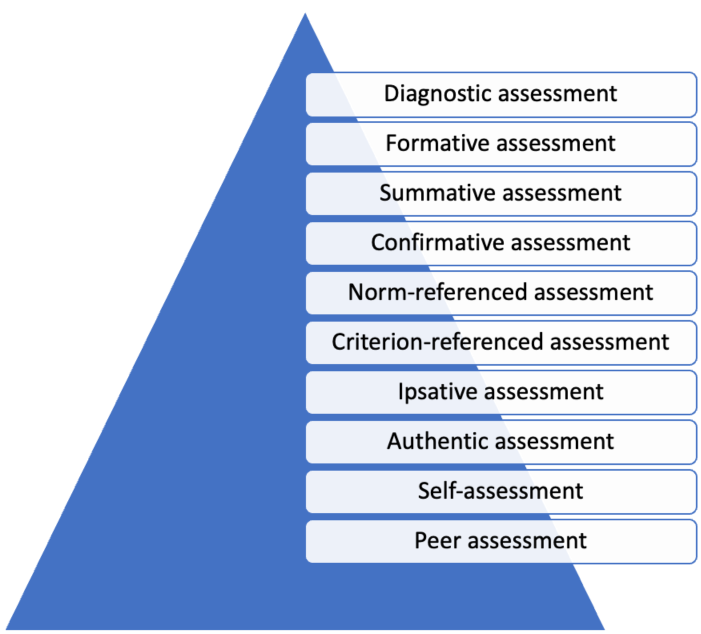

Figure 2.4.1. Types of Assessment

- **Confirmative assessment.** Confirmative assessment is the process of continuous improvement. They are built based on the results of formative assessment and summative assessment. They are used to analyse whether the technique that the tutors are following are still effective. After those necessary adjustments are made in the educational process to enhance the output and efficiency. If required various performance improvement programmes are conducted. A confirmative assessment ensures the success of your instructions year after year.
- **Norm-referenced assessment.** Norm-referenced assessment is the process of evaluating (and grading) the learning of students by judging (and ranking) them against the performance of their peers. Through norm-referenced assessments, you can determine students' proficiency by comparing it with local, state, or national standards. In norm-referenced assessment student's performance are compared against an average norm. This type of assessment is done to check the knowledge or skills of the students amongst a group.
- **Criterion-referenced assessment.** Criterion-referenced assessment measures student's performances against a fixed set of predetermined criteria or standards of learning. The student's performance is not compared to other students' performance on the same assessment.
- **Ipsative assessment.** Ipsative assessment measures the performance of a student against previous performances from that student. Ipsative assessment support effort-based attributions, primary goal is to motivate students to learn. It is more concerned with personal achievement by increasing students' awareness about their own learning advancement.
- **Authentic assessment.** Authentic assessments simulate real-world tasks and contexts, allowing students to apply their knowledge and skills in meaningful ways. These assessments often require problem-solving, critical thinking, and creativity, as they closely mirror situations students may encounter beyond the classroom. Examples of authentic assessments include case studies, projects, simulations, and performances. Authentic assessments not only assess students' understanding but also develop their transferable skills, such as collaboration and communication.
- **Self-assessment.** Self-assessments encourage students to reflect on their own learning and progress. By assessing themselves against predetermined criteria or learning objectives, students become more aware of their strengths and areas for improvement. Self-assessments can take the form of journals, checklists, reflection papers, or self-evaluations. By actively engaging in self-assessment, students take ownership of their learning and develop metacognitive skills necessary for lifelong learning.

- **Peer assessment.** Peer assessments involve students evaluating the work and performance of their classmates. By actively participating in the assessment process, students gain a deeper understanding of the criteria being assessed while also developing their own critical thinking and analytical skills. Peer assessments can be conducted through group projects, presentations, or anonymous evaluations. This type of assessment promotes collaboration, provides valuable feedback, and helps students develop a sense of fairness and objectivity.

Choosing the appropriate type of assessment depends on several factors, including learning goals, content, student characteristics, and available resources. By employing a variety of assessments, educators can gather a comprehensive and accurate representation of student learning while also supporting the development of a range of skills and abilities.

Formats of Assessment in Online Learning Environment

There are many formats of assessment in online learning environments. Some examples include:

- **Case studies** prompt students to put concepts, theories, and policies into a specific context and support the development of critical thinking skills, allow students to learn from one another, and encourage practical reasoning while generating strategies and solutions to real issues.
- **Reflections.** Critical reflection essays are often written at the end of a course as an opportunity for students to look back on their learning throughout the course. Embedding a reflective component within other assignments allows to gauge how learning is developing through these tasks.
- **Infographics** develops students critical thinking and communication skills. Infographics make great assignments when needed to make connections, discern the most relevant information, and communicate it in a different way.
- **Online discussions.** Thoughtful discussion prompts allow students to explore course concepts, gain new perspectives and understanding, participate actively and collaboratively in online courses.
- **Online student presentations**, whether live or pre-recorded, allow students to express their learning in different modes – spoken words, gestural expression, and often with images/visual aids. Students learn the skills of verbal expression and knowledge translation

- **Podcast assignments** allow students to demonstrate their learning in a different mode; students can expand on traditional knowledge generation and translation approaches by using strategies such as including portions of interviews, adding relevant sounds, music, etc.
- **Open book exams.** Open book, or open resource, exams provide dynamic opportunities for students to connect course materials with their previous learning by analysing, synthesizing, critiquing, and/or evaluating information; require students to connect course material to solve real-world scenarios or problems.
- **Annotated bibliography** provides students with the opportunity to strengthen skills in finding appropriate research literature, reading critically to assess the contributions of various articles, and writing concisely and coherently for a broader academic audience.
- **Media critique** critiquing a current media source can be a meaningful learning experience that allows students to make connections between their daily lives and course content.
- **E-portfolio** process of selecting the best examples of learning in a course or program can be illuminating as students see how far they have come; learning becomes visible as students organize artifacts that showcase their knowledge and skills.
- **Learning journal** students are required to write critically about what they have learned, drawing upon their experiences and/or practice, and relating it to their reading; enabling students to demonstrate complex learning outcomes including critical thinking.

In conclusion, assessment is an important part of the cycle of learning, which also includes outcomes (what?), strategies (how?), and content. Assessment is an integral part of the planning process and must coalesce with all other aspects of the intended learning experience, whether in terms of course or program. Assessment permits learners to engage with open-ended tasks that sustain learning and the learning cycle. Assessment presents learners with opportunities to make connections with prior knowledge and to build relationships between their own learning.

Understanding Assessment Design

Assessment design refers to the deliberate and systematic process of creating assessments that align with desired learning outcomes. It involves selecting appropriate assessment methods, developing suitable tasks or questions, establishing grading criteria, and ensuring validity and reliability of the assessments.

Key Considerations in Assessment Design

When designing assessments, several factors need to be taken into account to ensure their effectiveness. These include:

- **Alignment with Learning Outcomes.** Assessments should be closely aligned with the intended learning outcomes of a course or training program. This alignment ensures that the assessment measures what it is intended to measure and provides a reliable indicator of learner achievement.
- **Validity.** Assessments should possess validity, which means they accurately measure the knowledge or skills they are intended to assess. Validity can be established through careful consideration of the content and format of the assessment, as well as the expertise of subject matter experts.
- **Reliability.** Reliability refers to the consistency and stability of assessment results. Designers should aim to create assessments that yield consistent results when administered multiple times under similar conditions. Reliability can be enhanced through well-defined grading criteria and training of assessors.
- **Authenticity.** Authentic assessments reflect real-world situations and tasks that learners are likely to encounter in their future endeavors. Designing assessments that align with real-life contexts helps ensure that learners can transfer their acquired knowledge and skills effectively.
- **Engagement.** Engaging assessments capture learners' interest and motivate them to demonstrate their knowledge and skills to the best of their abilities. Incorporating interactive elements, real-life scenarios, and multimedia can enhance engagement and lead to a more accurate assessment of learners' capabilities.
- **Balance.** A well-designed assessment should strike a balance between various assessment methods, such as formative and summative assessments, as well as different types of tasks or questions. This balance ensures a comprehensive evaluation of learners' progress and learning outcomes.

Selecting Assessment Methods

There are various types of summative assessment methods and tools, each with its own advantages and challenges. Designers need to consider diverse assessment methods and tools that suit the specific learning outcomes they aim to measure. Some common assessment methods include:

- *Written Assessments:* These include essays, short-answer questions, and multiple- choice questions. They are useful for evaluating learners' understanding of theories, concepts, and factual knowledge.
- *Performance Assessments:* These require learners to apply their knowledge and skills in real or simulated scenarios. Performance assessments can involve practical tasks, presentations, portfolio assessments, or simulations.
- *Oral Assessments:* Oral assessments involve interviews, debates, presentations, or discussions. They allow for the evaluation of learners' oral communication skills, critical thinking abilities, and ability to articulate their ideas effectively.
- *Observational Assessments:* These assessments involve direct observation of learners' performance, such as in laboratory experiments, simulations, or workplace settings. They ensure a comprehensive evaluation of learners' practical skills.

Traditional Summative Assessment Tools

- *Examinations:* These include multiple-choice tests, short answer questions, and essay exams. They are widely used due to their ease of administration and scoring.
- *Standardised Tests:* These are norm-referenced tests that provide comparative data on student performance across different institutions.

Performance-Based Tools

- *Projects:* These involve complex, multi-step tasks that integrate knowledge and skills.
- *Portfolios:* These are collections of student work that demonstrate learning progress and achievement over time.
- *Presentations:* These assess students' ability to articulate their knowledge and skills verbally and visually.

Alternative Tools

- *Peer Assessments:* These involve students evaluating each other's work, promoting critical thinking and self-assessment skills.
- *Self-Assessments:* These encourage students to reflect on their own learning and identify areas for improvement.

VIDEO 2.4.3. Assessing Online Learning: Introduction to Online Assessment [*duration 2:26 minutes*]: https://www.youtube.com/watch?v=QPyKrxNCtr8

Designing Assessment Tasks

After selecting an appropriate assessment method, designers need to create tasks or questions that accurately measure the desired learning outcomes. Some key considerations in task design include:

- *Clear Instructions:* Tasks should provide clear instructions to prevent ambiguity and confusion among learners. Well-defined instructions help learners understand the purpose, requirements, and expectations of the assessment.
- *Authenticity:* Tasks should be authentic and relevant to the real-world application of knowledge and skills. They should mirror the challenges learners may encounter in their future professional contexts.
- *Appropriate Difficulty:* Tasks should be appropriately challenging and match the intended cognitive level of the learning outcomes. Tasks that are too easy or too difficult can lead to inaccurate assessments of learners' abilities.
- *Variety:* Designers should consider incorporating a variety of tasks or questions that assess different aspects of the learning outcomes. This variety ensures a comprehensive evaluation and prevents over-reliance on a single assessment method.
- *Time Considerations:* Tasks should be designed with realistic time constraints to mirror real-life situations in which learners must complete tasks within a given timeframe.

Designing effective assessments requires careful consideration of various factors such as alignment with learning outcomes, validity, reliability, authenticity, engagement, and balance. The selection of appropriate assessment methods, thoughtful design of assessment tasks, and establishment of clear grading criteria contribute to accurate and reliable assessment outcomes. By designing assessments that effectively measure learning outcomes, educators and trainers can gain valuable insights into learners' progress and facilitate their continued growth and development.

Establishing Grading Criteria

Grading criteria provide a clear framework for evaluating learner performance and assigning grades or scores. Key considerations in establishing grading criteria include:

- *Alignment with Learning Outcomes:* Grading criteria should align closely with the intended learning outcomes, ensuring that learners' achievements are accurately assessed.
- *Clarity and Objectivity:* Grading criteria should be clear, specific, and objective to minimize subjectivity and ensure consistent grading across multiple assessors.
- *Differentiation of Achievement Levels:* Grading criteria should allow for differentiation of achievement levels, enabling the identification of learners' strengths and areas for improvement.
- *Weighting of Assessment Components:* Grading criteria should reflect the relative importance of different assessment components to ensure a fair and balanced evaluation.

Digital Assessment Tools

There are a variety of digital tools that can make **summative assessments** easier. For example,

- **Socrative.** For a comprehensive suite of technological tools tailored for student assessment, this platform offers a diverse array of options. It supports the inclusion of multiple-choice, true/false, and short-answer questions, enhancing the flexibility of assessment formats. Notably, the platform allows instructors to view student results in real time, which facilitates immediate insight into student performance. Additionally, it provides the capability to add explanatory notes for incorrect answers, fostering a deeper understanding among students.
- **Floop**. Regardless of the grade level or subject matter, the grading process often demands significant time and effort, which educators frequently find in short supply. Introducing Floop, a cloud-based platform designed to streamline the feedback process. This tool enables students to receive detailed, annotated feedback from both instructors and peers. Students can upload images of their assignments using any internet-connected device, facilitating ease of access and use. Instructors can then annotate these images, placing markers at specific points to provide targeted feedback. This system allows students to view and respond to comments, thereby establishing a continuous feedback loop that enhances learning and comprehension.
- **Naiku.** Efficiently develop quizzes that students can complete using their mobile devices with this program. Additionally, it features a comprehensive repository of 60,000 standards-aligned

question items and 300 pre-constructed assessments, providing extensive resources to facilitate the creation of robust and aligned evaluations.

Students benefit from instant feedback, which can be configured to suit various instructional approaches; quizzes can be set to self-paced mode or conducted in a teacher-led format. A particularly commendable feature is the "Space Race," a collaborative quiz activity wherein student groups compete to reach the finish line, thereby promoting engagement and interactive learning.

- **Seesaw.** Portfolios serve as an excellent tool for summative assessment, enabling educators, students, and families to review a curated collection of student work and assess developmental progress over time. Traditional paper portfolios, however, are susceptible to being misplaced and present challenges in terms of sharing and grading. An effective alternative is to utilize an online portfolio platform, such as Seesaw, which mitigates these issues by providing a digital solution that is easily accessible, shareable, and more convenient for evaluative purposes.
- **Book Creator**. This represents an alternative form of portfolio assessment. Instead of merely aggregating their work over time, students utilize the program to actively construct a digital compendium that illustrates their learning outcomes.

Several digital formative assessment tools can be used:

- **Google Forms for Exit Tickets.** Exit tickets represent an excellent strategy for assessing students' comprehension of the day's lesson. To modernize this approach by replacing traditional sticky notes with a digital alternative, consider utilizing Google Forms. This platform is user-friendly and provides a convenient means of accessing student responses from any location at any time, thereby enhancing the efficiency and accessibility of formative assessments.
- **Kahoot!** This complimentary online quiz-game generator has gained widespread popularity, and justifiably so. Educators present the questions while students utilize a secure application on their personal devices, such as Chromebooks or smartphones, to submit their responses. These interactive games are highly engaging for students, making them an effective tool for enhancing classroom participation. Post-game, educators can analyze detailed reports to identify areas where students may require further instruction, thereby facilitating targeted remediation and mastery of learning objectives.

- **CommonLit.** CommonLit offers an extensive, free library of reading passages, each accompanied by integrated quizzes designed to assess comprehension. Educators can select articles based on topic, reading level, or genre, and assign them to students. The platform allows students to annotate texts and engage with guided reading questions as they progress through the material. Following their reading, students complete a comprehension quiz and participate in discussion questions, thus reinforcing their understanding and promoting critical thinking.
- **Flip. Flip** (formerly known as Flipgrid) is a video discussion platform modeled after social media, designed to facilitate class discussions on various topics, videos, or links posted to the class grid. Students can record video responses and share them with the teacher or the entire class. This platform is particularly effective for encouraging students to articulate and visualise their thought processes, thereby enhancing engagement and comprehension through interactive discourse.
- **Mentimeter.** Mentimeter is a dynamic tool that enhances presentations by incorporating interactive elements such as polls, word clouds, Q&A sessions, and more. This platform enables students to actively participate by voting on or responding to questions in real time, thereby fostering an engaging and interactive learning environment. The diverse range of formative assessments available through Mentimeter, administered instantaneously, is a key reason for its inclusion on our recommended list of educational technologies.
- **Jamboard.** Jamboard is a digital whiteboard seamlessly integrated with Google Workspace (formerly G Suite) services. It significantly enhances the focus on the learning process rather than solely on the final product. This tool is particularly favored by mathematics educators, as it allows students to solve problems and articulate their solutions effectively. For those not utilizing Google services, Padlet serves as a commendable alternative.
- **Literably.** Students can read aloud and respond to questions directly on their devices, with compatibility extending to nearly all types of devices. Within a 24-hour period, educators receive a running record that includes scores for accuracy, fluency, and comprehension. The free basic account provides access to 10 reading assessments per month.
- **Edpuzzle.** Edpuzzle is a versatile video editing tool that enables both educators and students to incorporate voice-overs, comments, supplementary resources, and quizzes into existing or self-created online videos. The most advantageous feature is the automatic collection of student responses, allowing educators to efficiently assess student understanding and engagement.

- **Pear Deck.** Pear Deck is an interactive presentation and lesson delivery tool designed to enhance student engagement. Using their devices, students can follow along with the teacher's slideshow displayed on a classroom screen. Throughout the presentation, teachers can pause at designated points to pose interactive questions, thereby collecting real-time data on student comprehension and understanding.
- **Quizalize.** The quizzes are meticulously tagged to educational standards, enabling educators to efficiently track mastery data for every question answered. These quizzes support a range of official state standards, including Common Core, TEKS, and others. Additionally, educators have the option to add hints or explanations, facilitating student learning as they complete the assessments.

Conclusion

In conclusion, this Lesson provides a comprehensive overview of the principles and strategies involved in creating effective assessments. Through an Introduction to Designing Assessments, learners gain an understanding of the importance of assessments and their role in measuring learning outcomes. The exploration of Types of Assessments and their uses equips participants with knowledge on various assessment methods such as formative and summative assessments, enabling them to choose the most appropriate approach based on the learning objectives. Finally, the module emphasizes the significance of validity and reliability in assessment design. Overall, this Lesson equips learners with the essential skills and knowledge needed to design assessments that promote effective learning and evaluation.

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Lesson 2.4.2. The Importance of Feedback in Online Learning

Learning Outcomes

By the end of this lesson, learners will be able to:

- Understand the role of feedback;
- Apply feedback models;
- Identify feedback dimensions, perspectives and good feedback characteristics;
- Design various feedback forms and strategies;
- Utilize e-feedback methods.

Lesson content

Introduction

Feedback is a critical component in student learning, serving as a catalyst for improvement and deeper understanding. It provides students with specific, actionable information about their performance, highlighting both strengths and areas needing development. Effective feedback fosters a growth mindset by encouraging learners to view challenges as opportunities for growth rather than as insurmountable obstacles. Additionally, it helps students set realistic goals and develop self-regulation skills, essential for lifelong learning. By promoting reflective practice, feedback enables students to critically assess their work and apply new strategies to enhance their academic skills, thereby bridging the gap between current performance and desired learning outcomes.

Feedback is a quantified dimensions of learners' feedback experiences can be leveraged to improve effectiveness, increase efficiency, and maintain appeal in online courses. Feedback should stimulate reflection, thought, learning, and improvement. Feedback and assessment go hand in hand. Learner-centred feedback is an essential component of quality assessment, which is part of the learning process.

VIDEO 2.4.4. Importance of Feedback in Online Learning [*duration 2:13 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88881/mod_book/chapter/2721/Feedback.mp4

A Model of Feedback to Enhance Learning

Hattie and Timperley (2007) presented a framework for feedback to enhance learning (see Figure 2.4.2). In this model, the authors suggest that as we reference current understanding and performance to a desired goal, feedback is the tool that helps to bridge that gap.

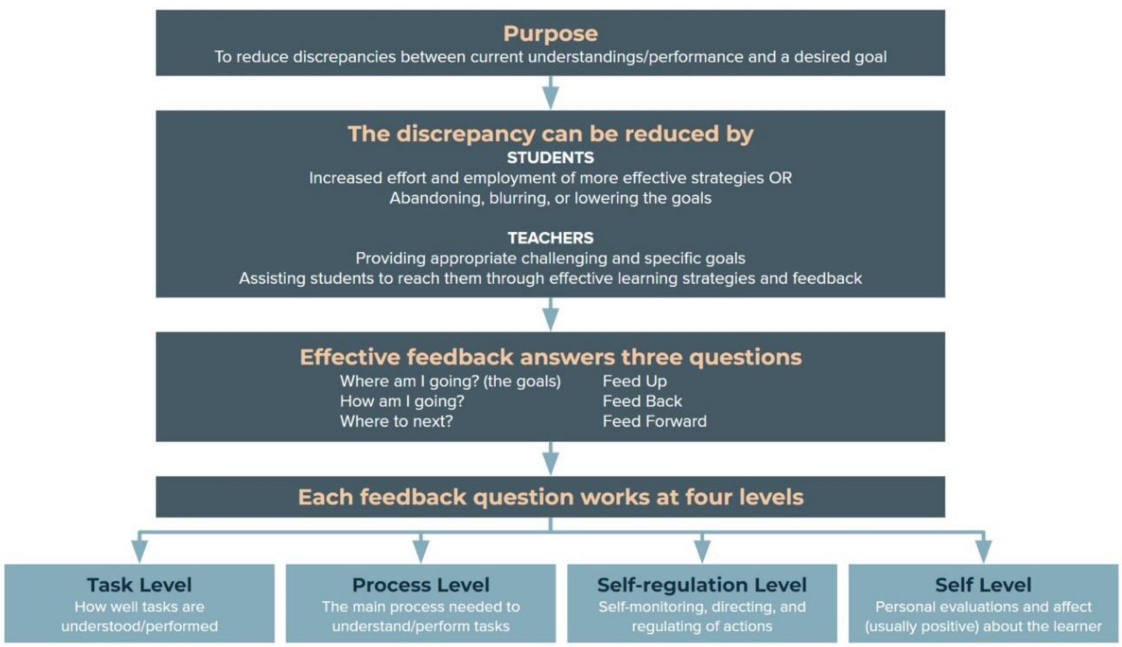

Figure 2.4.2. A Model of Feedback to Enhance Learning (Hattie and Timperley, 2007).

In an educational context, enhancing students' understanding and performance can be achieved by minimising obstacles to goal attainment. Students can either increase their effort, adopt more effective study strategies, accept lower standards, or give up altogether, which closes the gap between their performance and their goals.

Teachers play a crucial role in reducing this gap by clarifying goals, ensuring they are specific and appropriately challenging, and creating a conducive learning environment. They can equip students with effective learning strategies and error detection skills, with feedback serving as a critical component in bridging the gap between actual performance and desired goals (Hattie et al., 1996).

Effective teaching involves not only imparting knowledge but also evaluating and assessing students' understanding. Feedback should address three key questions:

- Where am I going? (Referencing the set goals)
- How am I going?
- Where to next?

These questions can be summarised as "feed up," "feed back," and "feed forward." Effective feedback should be focused and directed **at four levels** (Hattie and Timperley, 2007):

1. **Task Level:** Feedback on the specific task's understanding or performance. Example: "Consider using brighter colors to create a happier mood."
2. **Process Level:** Feedback on the process used to complete the task. Example: "Include a summary for each item mentioned to make the model clearer."
3. **Self-Regulation Level:** Feedback on the student's self-evaluation skills and confidence. Example: "You know the list of power words for compelling headlines. Ensure you've used them in your writing."
4. **Self Level:** Personal feedback not directly tied to a task. Example: "You are very hardworking. Your research effort is evident."

Effective feedback also involves timing and delivery. Immediate feedback may lead to quicker error correction, but delayed feedback can also be beneficial. For instance, correcting a public speaker immediately can be disruptive and reduce confidence.

Teachers should differentiate between feedback and advice. Feedback should be descriptive and followed by advice if necessary. For example, instead of saying, "Use brighter colors in your painting," a teacher could say, "Your painting progress is good. May I give you feedback to enhance it? The dark colors blend into the background; consider using brighter colors to make it stand out."

By following these principles, teachers can provide feedback that is more likely to be understood and accepted, ultimately leading to improved student performance

Dimensions of Feedback

Effective feedback is crucial for enhancing the learning experience and promoting student success. Several key dimensions of feedback contribute to its impact on learners:

- **Timeliness:** How quickly is feedback provided to the learner? This refers to the interval between a learner’s attempt and the response from either a peer or an instructor.
- **Frequency:** How often is feedback received? This measures the number of feedback instances experienced by the learner within a given unit of study.
- **Distribution:** How are interactions dispersed throughout the learning experience? This considers the intervals between feedback instances, ensuring they are spread out evenly to support continuous learning.
- **Source:** To what extent does the learner trust the feedback provider? This evaluates the credibility of the feedback source as perceived by the learner.
- **Individualisation:** How well is the feedback tailored to the learner’s unique strengths, needs, or interests? This assesses whether the feedback is specific to the learner's personal goals, strengths, needs, or questions.
- **Content:** How useful is the feedback content for the learner? This examines whether the feedback provides clear next steps to correct misunderstandings or encourages the learner to extend their learning in new and innovative ways.

Incorporating these dimensions into feedback practices can significantly enhance the educational experience, fostering deeper understanding and sustained academic growth.

VIDEO 2.4.5. Effective Feedback [*duration 3:24 minutes*]:
https://www.youtube.com/watch?v=LjCzbSLyIwI&t=46s

Perspectives of the Feedback

To provide comprehensive feedback that aids students in enhancing their learning, it is beneficial to consider feedback from three distinct perspectives:

Microscope Lens: This perspective focuses on the detailed characteristics of the feedback message itself. It involves scrutinizing the specific words chosen to convey the feedback. What language did you use in your comments?

Camera Lens: This viewpoint treats feedback as a snapshot of the learning process. It prompts reflection on what the feedback reveals about the student's thinking. Additionally, it considers what the student has learned regarding their current status, their goals, and the necessary steps to achieve those goals.

Telescope Lens: This perspective emphasizes the long-term impact of the feedback. It examines whether students were given intentional opportunities to utilize the feedback within their instructional framework. Furthermore, it assesses whether the use of feedback resulted in improved understanding or higher quality work (Brookhart, 2016).

Characteristics of Good Feedback

Here are some characteristics of good feedback:

- Focuses on specific learning objectives: Feedback should be tied to specific learning objectives and should provide information on how well a student has met those objectives.
- Provides actionable suggestions: Feedback should include actionable suggestions for improvement. Students should be able to use the feedback to make changes to their work or approach to learning.
- Encourages reflection: Feedback should encourage students to reflect on their learning and identify areas for improvement.
- Is delivered in a timely manner: Feedback should be delivered as soon as possible after the work has been completed. This allows students to make use of the feedback while the material is still fresh in their minds.
- Is delivered in a respectful manner: Feedback should be delivered in a respectful and constructive manner that encourages students to continue learning.
- Offers praise and recognition: Feedback should not only focus on areas for improvement but also acknowledge areas where students have done well. Positive feedback can motivate students to continue to work hard and achieve their goals.

Overall, good feedback is an essential tool for promoting student learning and growth. It helps students understand where they are in their learning journey and provides them with the information they need to make progress toward their goals.

Forms of Feedback

A feedback strategy can take many forms, depending on the specific learning objectives and the needs of individual students. Some common approaches to providing feedback in education include:

- Written feedback: Written feedback is one of the most common forms of feedback in education. Teachers may provide comments on students' assignments, projects, or assessments, highlighting areas of strength and making suggestions for improvement.
- Verbal feedback: Verbal feedback involves providing feedback to students in person or through video conferencing. This approach can be particularly useful for providing immediate feedback, answering questions and engaging in discussion about a student's progress.
- Peer feedback: Peer feedback involves having students provide feedback to each other on their work. This approach can be beneficial for promoting collaboration, building communication skills and developing critical thinking skills.
- Self-assessment: Self-assessment involves having students evaluate their own learning progress and performance. This approach can be beneficial for promoting self-reflection, encouraging metacognition and building self-confidence.

A feedback strategy can be an effective tool for promoting student learning and growth, as it provides students with valuable information and guidance to help them achieve their learning goals.

Designing Feedback Strategies

In education, a feedback strategy is a systematic approach to providing feedback to students on their learning progress and performance. The goal of a feedback strategy is to help students understand their strengths and weaknesses, identify areas for improvement and make progress towards their learning goals.

Each of these needs to be thought of in terms of 'effective and efficient'. Does it have a high impact on those reading the information and does it do so in a manner that can easily be digested?

A feedback strategy in education is a systematic approach to providing feedback to students on their learning progress and performance. The goal of a feedback strategy is to help students understand their strengths and weaknesses, set goals for improvement and take ownership of their learning.

A feedback strategy typically includes the following elements:

- Clear learning objectives: The teacher sets clear learning objectives and communicates them to students.
- Ongoing assessment: The teacher provides ongoing assessment of student learning, using a variety of methods such as formative assessments, quizzes, assignments and class discussions.
- Timely feedback: The teacher provides timely and specific feedback to students on their progress towards the learning objectives.
- Self-reflection: The teacher encourages students to reflect on their learning process (metacognition), their learning progress and identify areas for improvement.
- Goal setting: The teacher helps students set goals for improvement based on the feedback provided.
- Action planning: The teacher helps students develop action plans to achieve their goals.

By using a systematic feedback strategy, teachers can help students to improve their performance, boost their confidence and become more engaged in the learning process. It is also an effective way to support student growth and development over time.

Methods Suitable For E-feedback

Feedback is the comments, questions, and information on how students are achieving predetermined goal. Feedback methods are not discipline-specific, they are context-dependent (Costello and Crane, 2016).

Methods Suitable For E-feedback

- Automated tutors
- Auto-scoring of assignments
- Self-checks
- Written comments
- Oral comments
- Meta-verbal
- Emoticons

Automated tutors - computer-generated comments based on background programming; model answers or programmed feedback given in response to answers submitted to learners on computer-based assessments

Auto-scoring. Auto-scoring of assignments is used in educational games, or computer marked tests; differs from the automated tutor in that a score is provided; requires background programming.

Oral comments - spoken words, such as those used in group discussions; may be synchronous or asynchronous comments.

Written comments - exted-based comments placed on learner's work that tells the learner what is good about their work as well as how the work may be improved.

Self-checks - involve the learner reviewing the objectives to ensure they know what they are expected to know; self-checks are often found at the end of a chapter, or on the textbook's associated website.

Meta-verbal - meta-verbal feedback is provided using body language, tone, etc., that provide more information than words alone.

Emoticons - emoticons are word stamps, thumbs up, smiley faces or frowns that are quick and let the learner know what the teacher feels about a component of the work.

Peer feedback - involves learners critically thinking about their work and the work of others in order to make suggestions on ways to improve.

Automatic Feedback Generation in Online Learning Environments

Main goals for using automatic feedback generation:

- Use feedback to help students on a specific content/ course;
- Use feedback to support self-regulation;
- Use feedback to help instructors;
- Use feedback to reduce plagiarism behavior (Cavalcanti et al., 2021).

Figure 2.4.3. RISE Model for Clear and Effective Feedback

In conclusion, feedback is one of the most powerful influences on learning and achievement. Feedback has no effect in a vacuum; to be powerful in its effect, there must be a learning context to which feedback is addressed. Feedback is among the most critical influences on student learning.

Conclusion

In conclusion, the comprehensive analysis of student feedback underscores its critical importance in shaping educational strategies and enhancing the overall learning experience. This chapter has illuminated the multifaceted nature of student feedback, revealing its role not only as a mechanism for immediate course improvement but also as a foundational element in fostering a responsive and adaptive educational environment. Through detailed examination of various feedback modalities - ranging from qualitative reflections to quantitative surveys - our discussion highlights the necessity of incorporating diverse perspectives to capture the full spectrum of student experiences. Moreover, the insights derived from feedback serve as invaluable tools for instructors, enabling the refinement of pedagogical approaches and the alignment of instructional objectives with student needs. Future research should continue to explore innovative feedback methodologies and their long-term impacts on educational outcomes, ensuring that student voices remain integral to the continuous evolution of academic programs. By prioritizing and effectively integrating student feedback, educational institutions can cultivate a culture of continuous improvement, ultimately enhancing both teaching efficacy and student success.

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Lesson 2.4.3. Open Digital Badges

Learning Outcomes

By the end of this lesson, learners will be able to:

- Define Open Digital Badges and understand their significance in the context of digital education;
- Identify and explain the various goals and roles of Open Digital Badges in recognizing, motivating and assessing learning;
- Analyse the key characteristics and functions of Open Digital Badges and their impact on personalised learning pathways;
- Evaluate the advantages and challenges associated with the implementation of Open Digital Badges in educational and professional settings;
- Critically assess the potential disadvantages and criticisms of using Open Digital Badges.

Lesson content

Introduction

Open digital badges are a type of digital credential used to recognize and verify the acquisition of specific skills, knowledge, or achievements. They serve as an alternative to traditional forms of assessment and credentialing, offering a flexible and accessible way to validate and showcase competencies.

There are several definitions of Open or Digital Badges. Mozilla Foundation (Mozilla Foundation, 2012) defines Open Badges as “a symbol or indicator of an accomplishment, skill, quality or interest used to set goals, motivate behaviors, represent achievements and communicate success in many contexts”. Grant

(2016, p. 3) defines Open Badges as „digital image files that contain metadata, and their origins are inseparable from the ethos of open-source code and software protocols ". Liyanagunawardena et al. (2017) define Open Badges as "a digital representation of skills or accomplishments recorded in a visual symbol that is embedded with verifiable data and evidence. They are created following a defined open standard, so that they can be shared online".

Thus, Open Badges, also referred to as Digital Badges or Educational Badges, are visual symbols or digital representation of knowledge and skills, learning achievements or experience for certifying and recognising learning acquired from different educational providers, and packed with data and evidence that can be shared across the web. While a Digital Badge is an online representation of a skill the learner has earned, Open Badges take that concept one step further, and allow learners to verify their skills, interests and achievements through credible organisations (Virkus, 2019).

On its surface, a badge is nothing more than an image file encoded with metadata such as which organisation awarded it, the name and description of the badge, what skill, competency or achievement the badge represents, the criteria for earning the badge, the date of issue, if and when it expires, and links to evidence for why it was awarded. With support from the MacArthur Foundation, Mozilla developed an Open Badges Infrastructure (OBI), an open standard that was released in 2012. The OBI is a key element in the adoption and success of an ecosystem of badges, designed to support a broad range of different badge issuers, and to allow any user to earn badges across different issuers, web sites and experiences, and then combine them into a single collection tied to their identity (Virkus, 2019).

VIDEO 2.4.6. Open Digital Badges [*duration 1:59 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/88883/mod_book/chapter/2728/ODB.mp4

VIDEO 2.4.7. What is a Badge? [*duration 2:44 minutes*]: https://www.youtube.com/watch?v=HgLLq7ybDtc&t=16s

VIDEO 2.4.8. What are Open Digital Badges? [*duration 5:35 minutes*]:
https://www.youtube.com/watch?v=q3dkGupx0ac&t=3s

Goals and Roles of Open Digital Badges

The role of badges as competency credentials and as bridges from informal to formal learning increase the potential of open badges for changing teaching, learning and assessment processes. One potential for open badges is to award credentials for alternative forms of learning experiences acquired outside formal education settings.

(Bryan Mathers image collection, https://bryanmmathers.com/)

Hickey (2012) identifies three types of primary goals for using badges:

1. showing what somebody has done or might be able to do,
2. motivate individuals to learn or do and
3. transform or create learning systems.

Gibson et al. (2016) outline three primary roles of Open Badges for supporting learning journeys in higher education:

1. bringing visibility and transparency to learning, teaching and assessment;
2. revealing meaningful, identifiable and detailed aspects of learning for all stakeholders;
3. providing a new mechanism to recognise skills, experience and knowledge through an open, transferable, stackable technology framework (Virkus, 2019).

Joseph (2012) presents six frameworks for examining digital badging for learners to explain why people align themselves with badges and what their goals are in using badges. The six frameworks include:

1. badges as alternative assessment;

2. gamifying education with badges;
3. badges as learning scaffolding;
4. badges to develop lifelong learning skills;
5. badges as digital media and learning driver, and
6. badges to democratise learning.

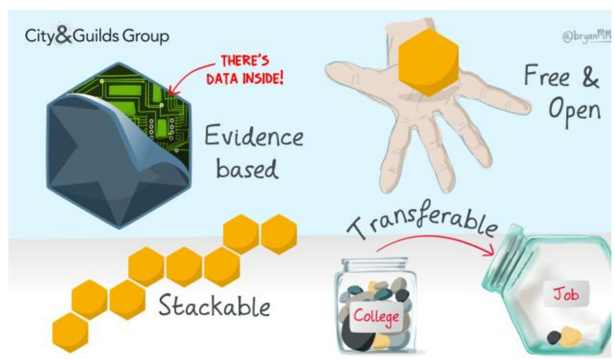
These are the main reasons for using Open Digital Badges as reflected in the literature (Virkus, 2019).

Characteristics of Open Digital Badges

Many of the characteristics of Open Digital Badges make them well suited to support personalised ways of learning and allow learners to choose their own pathways through learning content.

Open Digital Badges are:

- ***free and open:*** a free software and an open technical standard allow any organisation to use, create, issue and verify Open Digital Badges;
- ***transferable:*** badges earned in one environment can be shared in another - they can be transferred from one backpack to another and from one online platform to another;



(Bryan Mathers image collection, https://bryanmmathers.com/)

- ***stackable:*** badges from one organisation's system can build upon ones from another system and be stacked to tell the full story of learner's skills and achievements;
- ***evidence-based:*** each badge has metadata which is hard-coded into the badge image file that links back to the issuer, criteria and verifying evidence (Mozilla, 2019, para. 3).

Goldberg adds *transportability* and the *granularity*. Transportability refers to the ability of the badge to follow the badge earner through his lifetime and be recognised in a variety of environments. Granularity emphasises the need for specific data and details about why and how the badge was earned, so that anyone viewing it will have a clear understanding of the competencies of the badge owner (Virkus, 2019).

Functions of Open Digital Badges

Hickey (2012b) outlines four major functions for Open Digital Badges: recognising learning, assessing learning, motivating learning and evaluating learning.

(1) *Recognising learning* - this is the primary function of badges as they can capture various skills and achievements and provide a detailed picture of learners' skills, experience, achievements and qualities;

(2) *Assessing learning* - according to Hickey (2012a) assessing learning is one of four major functions for Open Digital Badges. Badges can help: (1) drive innovation around new types of assessments; (2) provide more personalised assessments for learners and (3) move beyond out of date or irrelevant testing practices. However, there are multiple assessment options for earning a badge and ensuring that the needs of each learner are met including course organisers, peers, or learners themselves. Nearly every application of Open Digital Badges includes some form of assessment: for example, summative, formative, transformative, instructor-, peer-, and self-assessment (Hickey 2012a, 2012b);

(3) *Motivating learning* - much of the concern and applause for badges centres around the idea of motivation. Some authors believe that badges are motivating students because of its playful nature. However, there are concerns about the well-documented negative consequences of extrinsic incentive on intrinsic motivation and free choice engagement. Therefore, some authors argue that we should not use badges to motivate learning. However, Hickey (2012b, para. 7) notes, that if we use badges to recognise and assess learning, they are likely to impact motivation.

(4) *Evaluating learning* - badges have enormous potential for helping teachers, schools, and programs evaluate and explore learning. Each badge has eight bits of information ("metadata") which will be recorded and easily accessible as a database (Virkus, 2019).

VIDEO 2.4.9. Get Started with Digital Badges! [*duration 10:48 minutes*]: https://www.youtube.com/watch?v=fHKEZ232-j0&t=9s

Advantages of Open Digital Badges

Open Digital Badges offer several advantages for learners, teachers, peers and potential employers. Open Digital Badges can be given for several reasons, for example, to recognise, verify, validate, motivate, evaluate or study learning. Open Digital Badges enable to:

- *Recognise* informal learning and 'soft skills' such as leadership, collaborative skills, critical thinking, problem solving, decision-making, time management, imagination, innovation, initiative, communication, independence or new skills and literacies such as digital, media and visual literacies. Open Digital Badges can capture more specific skills that might otherwise go unrecognised through formal academic processes, and capture the learning path and history and give a more holistic, accurate picture of educational achievement of the learner in comparison to traditional degrees or certificates;
- *Verify and communicate* concrete evidence and proof of skills, achievements and success to potential employers, professional networks, educational organisations and communities. The opportunity to present work and skills to the employer is a new experience in non-formal learning with people who are trying to promote and present themselves;
- *Find* and *hire* suitable employees for an employer, find people and communities with similar interests. Although the indexing and referencing program for badge credentials is still under development, it is possible in the future easily find certification organisations and courses. Such a directory would be necessary, in particular, for the user to search by subject for the issuer and qualification;
- *Monitor and support learning* - teachers receive information about the student's results and achievements that helps support learning, facilitate individualised and multiple learning pathways, particularly critical for professional learning development in fields that are rapidly changing and where formal programs may not be in step with emerging trends, technologies and practices; badges also allow to promote specific types of student behaviours;
- *Motivate* participation, learning, behaviours and achievement of learning outcomes; badges provide feedback, milestones and rewards throughout a course or learning experience, encouraging engagement and retention, as well as reinforcing a sense of achievement;

- *Enhance identity and reputation* - badges raise the learner's profile with the learning community and peers, giving the individual control over their online identity and reflect ongoing professional growth;
- *Provide branding opportunitie* and increase awareness of organisations and learning communities, being valuable to issuing institutions from a marketing perspective.

Thus, Open Digital Badges can transfer learning across spaces and contexts and make skills more portable across jobs, learning environments and places. They move faster to support and recognise new skills than traditional degree or certificate programs (Virkus, 2019).

Badge Design Patterns

Wills and Xie (2016) present a range of related theories that could support the design of Open Badges, including enabling learning autonomy and personalisation from the self-regulated learning perspective, goal setting, and pertinent motivating factors found in digital games. The culmination of these theories is then presented as a comprehensive framework.

Bryan Mathers image collection, *https://bryanmmathers.com/)*

Casilli (2012) provides seven ways of looking at a badge system and its design which includes philosophical, conceptual, pedagogical, visual/aesthetic, technical, categorical and ownership aspects. She notes that it is not an exhaustive list by any means, but it is simply an opportunity to unpack our influences and perceptions as we begin the process of designing badge systems.

According to Põldoja and Laanpere (2014, p. 173) four potential emerging badge design patterns can be identified:

- Composite badges can be achieved by completing multiple assignments.
- Activity-based badges can be awarded automatically based on measurable learning activities.
- Grade-based badges are based on the grades that the learners have received, for example, ‘Bronze’, ‘Silver’ and ‘Gold’ badges.
- Hierarchical badges are divided into several levels, some of which may be composite badges based on lower-level badges.

As badges are open and interoperable, then everybody can use whatever technologies they need and utilise badging in whatever way suits their own community of badge earners (Badges/FAQs, n.d.). There are many organisations who have created infrastructure to support the use of badges, and to create, distribute and support the circulation of open badges for both individuals and organisations. For example, Acclaim, Badgecraft, BadgeOS, Badgr, Bestr, Credly, ForAllRubrics, MOUSE Create, Open Badge Factory, P2PU Badges, ProExam Vault, RedCritter are some examples of the platforms available to support badge system development and deployment (Virkus, 2019).

Disadvantages and Challenges of Using Open Badges

There are both supportive and critical opinions on the use of Open Digital Badges in education. Several authors express concern related to motivation in earning badges. The main argument is that learners will focus on accumulation of badges (extrinsic motivation) rather than on the process of learning (intrinsic motivation). There is also fear that badges run the risk of contributing to the ’gamification’ of education or bring too much structure and hierarchy to learning that is not inherent in informal learning.

Some authors express concern how meaningful badges can become if any organisation is allowed to give them out for any reason and quality and status inevitably vary from one badge to another while many badges may not be designed well from an instructional design perspective, and do not guide learning effectively for a learner.

Some authors argue that badges may not appear as credible to potential employers as a paper credential from a recognised higher education institutions. Halavais (2012) just concludes that if badges are poorly applied, they will be bad and if used well, they can lead to peer learning and authentic assessment (Virkus, 2019).

Conclusion

The exploration of open digital badges in this lesson underscores their transformative potential in education and professional development. Open digital badges offer a versatile and robust mechanism for recognizing and validating a wide array of skills and achievements that traditional credentials may overlook. As these badges are digitally verifiable and shareable, they facilitate a more transparent and accessible way of demonstrating competencies to a global audience.

The adoption of open digital badges has been accelerated by advancements in technology and the increasing need for lifelong learning and continuous professional development. They support personalized learning pathways, enabling learners to acquire and showcase skills at their own pace and according to their own interests. This flexibility is particularly beneficial in addressing the diverse needs of learners in today’s dynamic educational and professional landscapes.

Moreover, open digital badges contribute to the democratization of education by providing equitable opportunities for recognition. They empower individuals from varied backgrounds to gain acknowledgment for their skills and achievements, thereby bridging gaps that traditional credentialing systems often leave unaddressed. This inclusivity is crucial for fostering a more equitable and diverse professional environment.

The integration of open digital badges into formal education and corporate training programs has shown promising results. Institutions and organizations that have embraced this innovation report enhanced learner engagement, motivation, and outcomes. However, the widespread adoption of open digital badges is not without challenges. Issues such as standardization, interoperability, and ensuring the credibility and quality of badges need continuous attention and collaborative efforts from educators, policymakers, and technology providers.

In conclusion, open digital badges represent a significant evolution in the way achievements are recognized and communicated. They have the potential to complement and enhance traditional credentialing systems, making skill recognition more dynamic, inclusive, and aligned with the demands of the 21st-century knowledge economy. As the ecosystem of open digital badges matures, ongoing research and dialogue will be essential to maximize their benefits and address emerging challenges, ensuring they fulfill their promise of transforming education and professional development.

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Self-Assessment Quiz

Test your knowledge by taking the **Self-Assessment Quiz** (https://open.ktu.edu/mod/quiz/view.php?id=17825) included in the 4th Topic "Assessment and Evaluation in Digital Education" of the MOOC "Digital Education" (https://open.ktu.edu/course/view.php?id=194).

Practical Assignment

Select and solve your challenge for **Enhancing Vocational Education with Telepresence Robots** (https://open.ktu.edu/course/view.php?id=194&section=5) by following the instructions described in the MOOC “Digital Education” (https://open.ktu.edu/course/view.php?id=194).

3. BIG DATA

Relevance: Information technologies with growing amounts of digital storage and more devices or sensors than ever before have resulted in massive quantities of diverse data, where applying this data for many useful purposes becomes challenging. Term Big Data indicates massive and often unstructured data, for which traditional data management and analysis tools are insufficient.

The aim of the course is to give an overview of the Big Data concept and main techniques for working with it effectively. Practical focus is on extracting value and formulating data-driven insights using analytics and visualization.

Learning outcome: by the end of the course, students should have a sufficient knowledge of big data analytics as a tool for addressing research questions and approaching challenging problems with data-driven solutions.

TOPIC 3.1. Definition of Big Data

After completing the Topic learners will be able to define main properties of big data and identify when data at hand needs big data tools.

Overview of this topic

- Tools for manipulating large datasets and performing analytics efficiently
- Utilization of distributed systems like Hadoop for fault tolerance and parallel computing
- Implementation of MapReduce for splitting, applying, and combining data operations
- Integration of streaming data solutions like Apache Kafka Streams and Apache Flink for real-time analytics
- Leveraging machine learning platforms such as H2O and Apache Spark MLlib for scalable algorithms

Big data: definition and taxonomy

- What is a big data?
- What are the main properties of big data?

Instructions for learning activities

1. See lesson's video;
2. Learn from slides & notes;
3. Read additional learning material presented bellow;
4. For support use chatbot bellow or chat with the notes.

Topic content

Introduction

Lesson 3.1.1. What is data?

Lesson 3.1.2. What is big data?

Lesson 3.1.3. Five dimensions

Lesson 3.1.4. Growing list of V's

Lesson 3.1.5. Big data's complex nature

Lesson 3.1.6. Daily data creation stats

Introduction

Big data refers to massive amounts of information that flood businesses daily, like a digital tidal wave too large for traditional tools to handle. As reported by SAS, this term encompasses not just the sheer volume of data, but also its variety and the speed at which it arrives, challenging organizations to find meaningful insights in this sea of information.

VIDEO 3.1.1. Fundamentals of big data analytics [*duration 15:47 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/63722/course/section/2357/Big%20Data%201.mp4

Lesson 3.1.1. What is data?

Figure 3.1.1. https://www.storytellingwithdata.com/blog/2020/9/24/what-is-a-table

Data can be thought of as a giant spreadsheet, where each row represents a specific example or case, and each column represents a different characteristic or feature. For instance, in a dataset about cars, each row might be a specific car model, while columns could include details like color, price, and fuel efficiency [1] [2] Big data is like having an enormous version of this spreadsheet with millions of rows, providing a much larger sample size to analyze. However, when the number of columns (variables) significantly exceeds the number of rows (cases), it can lead to a problem known as the "curse of dimensionality," which can make it challenging for algorithms to process and analyze the data effectively [3].

[1] https://www.stata.com/manuals/gsw1.pdf

[2] https://dtkaplan.github.io/SM2-bookdown/data-cases-variables-samples.html

[3] https://certificationanswers.gumroad.com/l/Google-Data-Analytics-Professional-Certificate-Answers

Lesson 3.1.2. What is big data?

Big data is like a massive, never-ending digital buffet with a wide variety of dishes to choose from [4]. This buffet is constantly growing larger and more diverse. The two main types of dishes at this big data buffet are structured data, which is like a neatly organized salad bar, and unstructured data, which is more like a big pot of mystery stew filled with all sorts of random ingredients [5].

Structured data is information that fits nicely into rows and columns, like numbers and categories. It's the kind of data you might find in a traditional database or spreadsheet [5]. Unstructured data, on the other hand, is all the messy stuff that doesn't fit neatly into boxes, like social media posts, emails, photos, and videos [5].

One fun way to think about big data is this: if you try to open a data file in a program like Microsoft Excel and your computer crashes or refuses to load the file, congratulations - you're probably dealing with big data [4]! Regular data is like a light snack that's easy to consume, while big data is like an all-you-can-eat buffet that's way too big for one person (or computer) to handle alone.

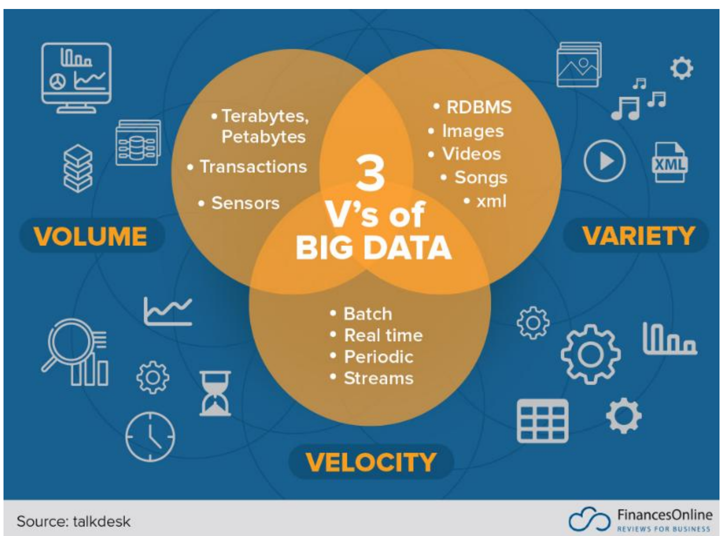

Figure 3.1.2. https://financesonline.com/what-is-big-data-analytics-and-how-it-helps-you-understand-your-customers/

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[4] https://www.techtarget.com/searchdatamanagement/definition/big-data

[5] https://www.webfx.com/blog/internet/what-is-big-data/

The three V's - volume, variety, and velocity - are like the secret spices that give big data its unique flavor [4]. Volume refers to the massive size of the datasets, variety is all the different types and formats of data, and velocity is the lightning-fast speed at which new data keeps pouring in [4]. Trying to analyze big data is kind of like trying to drink from a fire hose - it can be overwhelming!

But with the right tools and techniques, businesses and organizations can tap into the power of big data to make better decisions, improve operations, and gain valuable insights [4]. It's like having a crystal ball that can help you see patterns and trends you never knew existed. So, grab a plate and dig in - the big data buffet is open for business!

Lesson 3.1.3. Five dimensions

The journey from 3V's to 5V's of Big Data is like watching a simple recipe evolve into a gourmet dish. Initially, Big Data was defined by three key ingredients: Volume (the size of your grocery haul), Variety (different types of items in your cart), and Velocity (how quickly you're tossing items in) [6,7]. As our understanding matured, two more crucial ingredients were added. Veracity, like checking expiration dates, ensures data trustworthiness and accuracy [6,8]. Value, perhaps the most important, represents the nutritional benefit - the insights and advantages organizations gain from their data [6,8]. Just as a master chef carefully balances flavors, data scientists must skillfully manage these five V's to create valuable insights from the vast buffet of Big Data [9].

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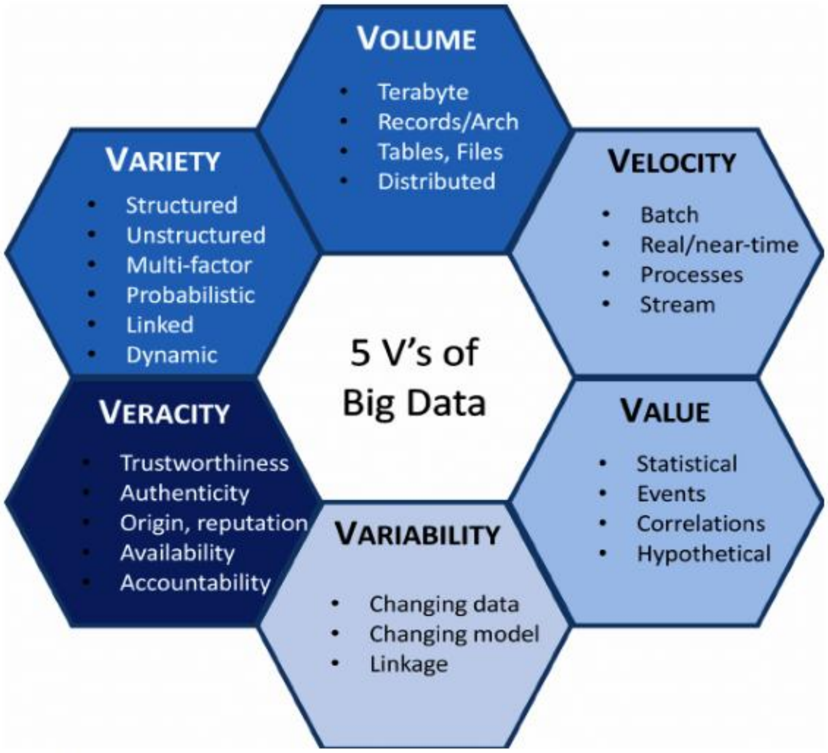
[6] https://www.bigdataldn.com/en-gb/blog/data-engineering-platforms-architecture/big-data-the-3-vs-explained.html

[7] https://www.techtarget.com/whatis/definition/3Vs

[8] https://www.techtarget.com/searchdatamanagement/definition/5-Vs-of-big-data

[9] https://www.auraquantic.com/five-vs-big-data/



The five V's of Big Data (Adapted from ("IBM big data platform - Bringing big data to the Enterprise," 2014))

Figure 3.1.3. https://www.researchgate.net/figure/The-five-Vs-of-Big-Data-Adapted-from-IBM-big-data-platform-Bringing-big-data-to-the_fig1_281404634

Lesson 3.1.4. Growing list of V's

The concept of the "V's" in Big Data has expanded over time, much like a snowball rolling down a hill, gathering more characteristics as our understanding grows. This evolution reflects the increasing complexity and nuanced understanding of Big Data in various contexts. Here's an overview of how the V's have multiplied:

- V's: The original framework introduced by Doug Laney in 2001, consisting of Volume, Velocity, and Variety [10].
- 5 V's: As discussed in the previous section, this expanded to include Veracity and Value[10.]
- 9 V's: Expanded by Owais et al. in 2016, adding:
    - Variability: Inconsistency in the data set.
    - Validity: How accurate and correct the data is for its intended use.
    - Vulnerability: Security and privacy concerns.
    - Volatility: How long the data is valid and should be stored [11].
- 10 V's: Data Science Central added:
    - Visualization: Making the data understandable and accessible [11]
- 17 V's: Panimalar et al. in 2017 further expanded the list to include:
    - Venue: The distributed heterogeneity in Big Data systems.
    - Vocabulary: The schema and data models.
    - Vagueness: The confusion and uncertainty in the data.
    - Verbosity: The increase in communication cost due to processing.
    - Voluntariness: The willingness to share data.
    - Versatility: The ability to adapt or change based on the data.
    - Viability: The importance of data quality to decision making.
    - Virality: The speed at which the data spreads [11].
- 42 V's: In 2017, KDNuggets published an extensive list of 42 V's, showcasing the ever-expanding nature of Big Data characteristics [11].

[10] https://etheses.lse.ac.uk/3981/1/Stelmaszak-Rosa__Big-data-analytics.pdf
[11] https://www.academia.edu/33142222/BIG_DATA_ANALYTICS_A_Practical_Guide_for_Managers

This expansion of V's demonstrates the evolving complexity of Big Data and the need for a more comprehensive understanding of its characteristics. However, it's important to note that while these additional V's provide valuable insights, the core concepts are still largely captured by the original 3 V's and the expanded 5 V's [10] [11].

The proliferation of V's is like a game of "buzzword bingo" in the Big Data world. While it's interesting to explore these additional characteristics, practitioners and researchers often focus on the most relevant V's for their specific use cases rather than trying to address all 42 at once. It's like choosing the right tools from a massive toolbox – you don't need every single one for every job, but it's good to know they're there if you need them.

Lesson 3.1.5. Big data's complex nature

Big Data is like a giant, ever-changing puzzle with pieces that don't always fit neatly together. It's an abstract concept that goes beyond just having a lot of information. Imagine trying to solve this puzzle while new pieces keep appearing, some pieces change shape, and others disappear!

This puzzle has some tricky features. Ambiguity is like having puzzle pieces without pictures - you're not sure where they go because there's no clear metadata after combining different data sources. Virality is how quickly puzzle pieces spread to other puzzlers - it's the speed at which data travels among users. Viscosity is like trying to move puzzle pieces through honey - it's the slowdown in data flows. Complexity arises when you're trying to fit pieces from many different puzzle sets together. Variability is like the puzzle changing size and shape unpredictably - it's the inconsistent speed of data coming in. These characteristics make Big Data a challenging but exciting field to work in, full of new possibilities and insights waiting to be discovered [12].

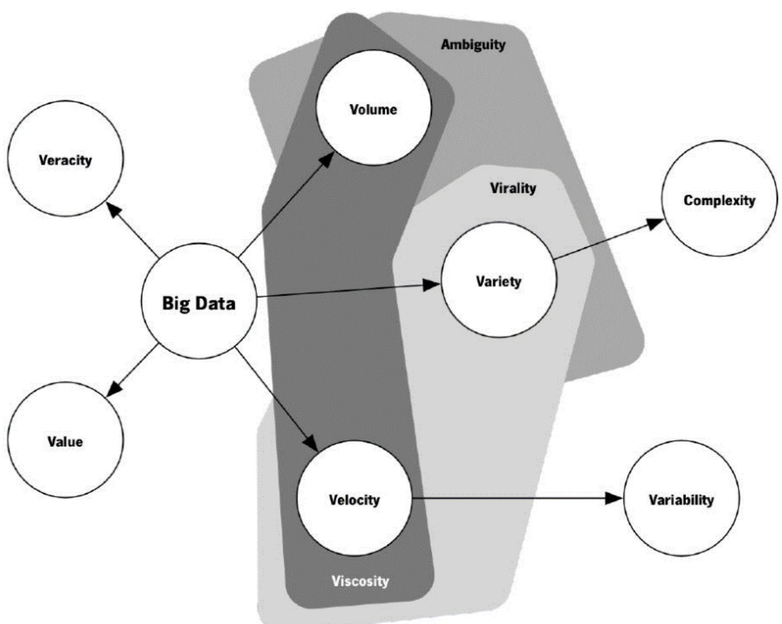


Figure 3.1.4. https://pplx-res.cloudinary.com/image/upload/v1724161549/user_uploads/wisrxagwr/Costa_Santos_2017_Fig_1.jpg

[12] https://www.iaeng.org/IJCS/issues_v44/issue_3/IJCS_44_3_04.pdf

Lesson 3.1.6. Daily data creation stats

Imagine the entire world's data as a giant, ever-growing mountain of digital information. Every day, we're adding more to this mountain than you can possibly imagine. Let's break down some mind-boggling statistics to help visualize just how much data we're creating:

- Daily Data Deluge: Every single day, we generate a whopping 328.77 million terabytes of data [13] That's like filling up 328.77 million 1TB hard drives every 24 hours!
- Yearly Data Mountain: By the end of 2023, experts predict we'll have created and consumed about 120 zettabytes of data [13]. To put that in perspective, if each gigabyte were a brick, you could build about 16 Great Walls of China with that much data!
- Personal Data Production: Each internet user creates about 1.7 MB of data per second [14]. That's roughly equivalent to a high-quality digital photo every second you're online.
- Social Media Tsunami:
  - Facebook users upload 147,000 photos every minute [15].
  - TikTok users watch 167 million videos every minute [15].
  - Twitter (now X) sees about 500 million tweets posted daily [14].
- Video Avalanche: YouTube users upload about 500 hours of video every minute [15]. That's like 30,000 hours of new content every hour!
- Search Engine Surge: Google processes over 3.5 billion searches per day[15]. That's more searches daily than there are people in India!
- Email Explosion: About 333.2 billion emails are sent every day [14]. If each email were a second, that would be over 10,500 years' worth of emails daily!

These numbers are so large they're hard to grasp, but they illustrate the incredible scale of our digital world. Every click, every post, every search is adding to this massive mountain of data. And it's not just about quantity - all this data holds valuable insights about human behavior, trends, and patterns that can be used to make better decisions in business, science, and everyday life.

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[13] https://financesonline.com/how-much-data-is-created-every-day/

[14] https://edgedelta.com/company/blog/how-much-data-is-created-per-day

[15] https://bernardmarr.com/how-much-data-do-we-create-every-day-the-mind-blowing-stats-everyone-should-read/

Lesson 3.1.7. Data sources and types

Big data is like a giant digital stew, with ingredients coming from all corners of the digital world. These ingredients come in different shapes and sizes, just like the vegetables and meats in a real stew. Here's a breakdown of where this data comes from and what forms it takes

Data Sources:

- Internet: The web is like a never-ending farmer's market, constantly supplying fresh data.
- Social Media: Platforms like Facebook and Twitter are like bustling town squares, generating massive amounts of user-created content.
- Web Services: These are like food delivery services, constantly transferring data between different applications.
- Sensors (IoT): Think of these as the kitchen thermometers of the digital world, constantly measuring and reporting data.
- Other Devices: Smartphones, tablets, and computers are like the pots and pans, tools that both create and process data.

Data Formats:

- Structured: This is like pre-cut vegetables, neatly organized in rows and columns. Examples include data from Customer Relationship Management (CRM) and Enterprise Resource Planning (ERP) system [16]
- Semi-structured: Think of this as partially prepared ingredients, like XML or JSON files. They have some organization but don't fit neatly into traditional database [17].
- Unstructured: This is the raw, unprocessed stuff - like whole vegetables or uncut meat. It includes documents, images, and videos that don't have a predefined data model [18].

Just as a good stew requires a mix of ingredients, big data analysis often involves combining these various sources and formats to create a rich, flavorful insight soup [19].

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[16] https://www.sap.com/lithuania/products/technology-platform/what-is-big-data.html
[17] https://cloud.google.com/learn/what-is-big-data
[18] https://www.reltio.com/glossary/data-analytics/what-is-big-data/
[19] https://www.nexusgroup.com/how-are-big-data-and-the-internet-of-things-connected/

Lesson 3.1.8. Unlocking big data's value

Extracting value from big data is like mining for gold in a vast digital landscape. To uncover the precious insights hidden within, data analysts use a variety of techniques. Here are some key methods for turning raw data into valuable [20] [21].

  - Use heat maps to identify patterns in large datasets [20].
  - Employ tree maps to display hierarchical data and spot important categories [20].
- Identify trends and patterns:
  - Use data mining techniques to sort through large datasets and find relationships [22].
  - Look for anomalies and outliers that may indicate interesting insights [21] [22].
  - Analyze historical data to spot recurring trends over time [22].
- Build predictive models:
  - Develop machine learning algorithms to forecast future outcomes based on past data [22].
  - Use deep learning to find patterns in complex, abstract datasets [22].
  - Create models that can identify upcoming risks and opportunities for the business [22].

By applying these techniques, organizations can transform their big data from a chaotic jumble into a treasure trove of actionable insights. Just as a skilled prospector knows how to sift through tons of rock to find valuable nuggets, data analysts use these tools to extract the most valuable information from the vast sea of big data

[20] https://www.vizio.ai/blog/best-predictive-analysis-for-effective-data-visualization-techniques
[21] https://www.analyticodigital.com/blog/importance-of-data-visualization-in-business-intelligence
[22] https://www.tableau.com/learn/articles/big-data-analytics

Conclusions

Big data is like a vast digital ocean, teeming with information from diverse sources. Here's a synthesis of the key points we've covered:

- Definition: Big data refers to massive, complex datasets that overwhelm traditional tools, characterized by the 5 V's:
    1. Volume (enormous size)
    2. Variety (diverse formats)
    3. Velocity (rapid generation)
    4. Veracity (data quality)
    5. Value (actionable insights)
- Sources and Types:
    - Sources include the internet, social media, IoT sensors, and various devices
    - Formats range from structured (databases) to unstructured (images, videos)
- Challenges:
    - Handling the sheer volume (328.77 million terabytes created daily in 2023)
    - Managing data variety and complexity
    - Ensuring data quality and relevance
- Value Extraction:
    - Visualization techniques to make data comprehensible
    - Pattern recognition to identify trends
    - Predictive modeling to forecast future outcomes

Big data is transforming how we understand and interact with information, offering unprecedented opportunities for insights and innovation. However, it also presents significant challenges in management, analysis, and ethical use. As our digital world continues to expand, mastering big data will be crucial for organizations and individuals alike [23] [24] [25] [26] [27].

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[23] https://www.insidehighered.com/blogs/gradhacker/step-step-synthesis

[24] https://www.bgsu.edu/content/dam/BGSU/learning-commons/documents/writing/synthesis/asked-to-synthesize.pdf

[25] https://www.simplypsychology.org/synthesising.html

[26] https://newunderthesunblog.wordpress.com/2015/06/30/writing-the-discussionconclusion-section/

[27] https://researchguides.uoregon.edu/litreview/synthesize

TOPIC 3.2. Tools for Big Data Analytics

After completing the topic learners will be able to recommend industry-grade big data tools.

Overview of this topic

- Tools for manipulating large datasets and performing analytics efficiently
- Utilization of distributed systems like Hadoop for fault tolerance and parallel computing
- Implementation of MapReduce for splitting, applying, and combining data operations
- Integration of streaming data solutions like Apache Kafka Streams and Apache Flink for real-time analytics
- Leveraging machine learning platforms such as H2O and Apache Spark MLlib for scalable algorithms

Instructions for learning activities

1. See lesson's video;
2. Learn from slides & notes;
3. Take a quiz: Big Data TEST A;
4. For support use chatbot bellow or chat with the notes.

Topic content

Introduction

In the dynamic field of big data analytics, tools such as HDFS, MapReduce, and Apache Spark MLlib are indispensable for managing, processing, and analyzing large datasets. HDFS ensures reliable data storage with fault tolerance through replication, MapReduce efficiently processes data in parallel, and Spark MLlib offers a comprehensive suite of machine learning algorithms, each playing a critical role in addressing complex data challenges and fostering innovation across various industries.

VIDEO 3.2.1. Tools for Big Data Analytics [*duration 14:05 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/63722/course/section/3876/ASSIST_Big_Data_2_%28video%29.mp4

Lesson 3.2.1. HDFS: reliable data storage

The Hadoop Distributed File System (HDFS) is like a super-reliable digital filing cabinet for massive amounts of data. Imagine a giant library where every book is copied and stored in multiple locations - that's how HDFS keeps your data safe.

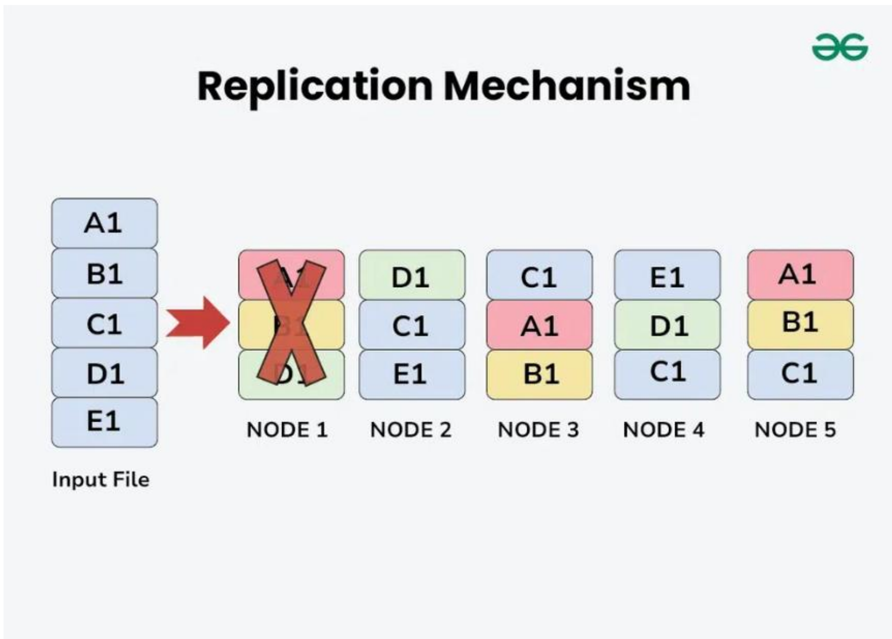

Figure 3.2.1. https://www.geeksforgeeks.org/how-does-hadoop-ensure-fault-tolerance-and-high-availability/

HDFS achieves fault tolerance primarily through data replication [28] [29]. By default, it creates three copies of each piece of data and spreads them across different machines in the cluster [29]. This is like having backup copies of your favorite books in different rooms of your house. If one copy gets damaged, you can always find another.

Here's how it works in practice:

1. Data splitting: HDFS breaks large files into smaller chunks called blocks, typically 128 MB in size [28]. Think of this as dividing a long book into chapters.

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[28] https://data-flair.training/blogs/learn-hadoop-hdfs-fault-tolerance/

[29] https://www.geeksforgeeks.org/how-does-hadoop-ensure-fault-tolerance-and-high-availability/

2. Block replication: Each block is replicated multiple times (usually 3) and stored on different machines called DataNodes [28 29]. This is like making photocopies of each chapter and storing them in different rooms.
3. Metadata management: A special machine called the NameNode keeps track of where all these blocks are stored [28 29]. It's like having a librarian who knows exactly where every book and its copies are located.

If a machine in the cluster fails (like a bookshelf collapsing), HDFS can still access the data from the other copies [29]. It's smart enough to automatically create new copies on other healthy machines to maintain the desired number of replicas [28].

HDFS also uses other techniques to ensure fault tolerance:

1. Heartbeat messages: DataNodes regularly send "I'm alive" signals to the NameNode [29]. If a DataNode stops sending these messages, the NameNode knows it has failed and can take action.
2. Checkpoints and recovery: The system periodically saves its state, allowing it to recover quickly if the NameNode fails [29].

In Hadoop 3, a new feature called Erasure Coding was introduced to improve storage efficiency while maintaining fault tolerance [28]. This advanced technique allows HDFS to provide the same level of data protection with less storage overhead.

By using these methods, HDFS ensures that your data remains safe and accessible even if parts of the system fail. It's like having a self-repairing, self-organizing library that keeps your information secure no matter what happens.

Lesson 3.2.2. MapReduce: split, apply, combine

MapReduce **Programming model for big data processing**	
Description	A programming model and implementation for processing and generating big data sets using a parallel, distributed algorithm on a cluster.
Components	Consists of a map procedure for filtering and sorting, and a reduce method for summarizing data (e.g., counting name frequencies).
Function	Facilitates parallel processing, data transfers, and offers fault tolerance and redundancy through its distributed servers.
Inspiration	Derived from map and reduce functions in functional programming, though serving different purposes in this context.
Key Advantages	Achieves scalability and fault-tolerance for various applications, primarily beneficial with multi-threaded implementations on multi-processor hardware.
Implementations	Many programming languages have MapReduce libraries; Apache Hadoop is a well-known open-source implementation.
Evolution	Originally a proprietary Google technology, it became genericized, and by 2014, Google moved to other big data processing models.

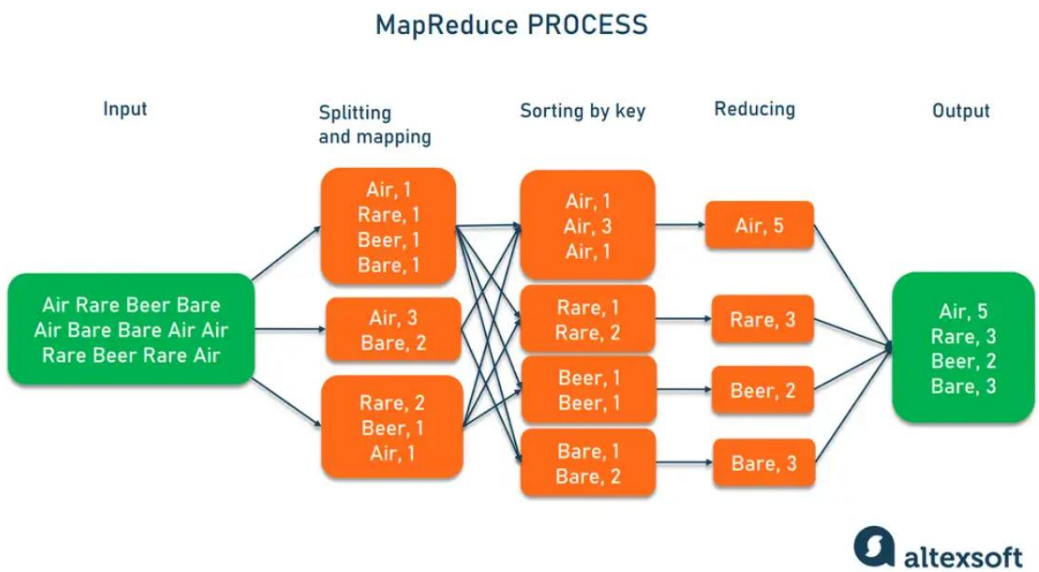

Figure 3.2.2. https://www.altexsoft.com/blog/hadoop-pros-cons/

MapReduce is like a giant assembly line for data processing. Imagine you're sorting a mountain of Lego bricks by color. Instead of doing it alone, you enlist an army of helpers. That's the essence of MapReduce - it breaks big jobs into smaller tasks that can be done simultaneously.

Here's how it works: First, the "map" step splits the data into chunks (like dividing the Lego pile among your friends). Each helper then applies a specific operation to their chunk (sorting their Legos by color). Finally, the "reduce" step combines all the results (merging all the sorted piles). This approach, inspired by functional programming concepts, allows for efficient processing of massive datasets across many computers [30]. It's particularly useful for tasks like counting word frequencies in large text collections or analyzing web logs. The beauty of MapReduce is that it handles all the complex behind-the-scenes work of distributing tasks, managing failures, and coordinating between machines, allowing programmers to focus on the core logic of their data processing tasks [31].

30 https://en.wikipedia.org/wiki/MapReduce

31 https://www.cs.princeton.edu/courses/archive/fall14/cos326/lec/21-seq-divide-conquer.pdf

Lesson 3.2.3. Hadoop ecosystem components

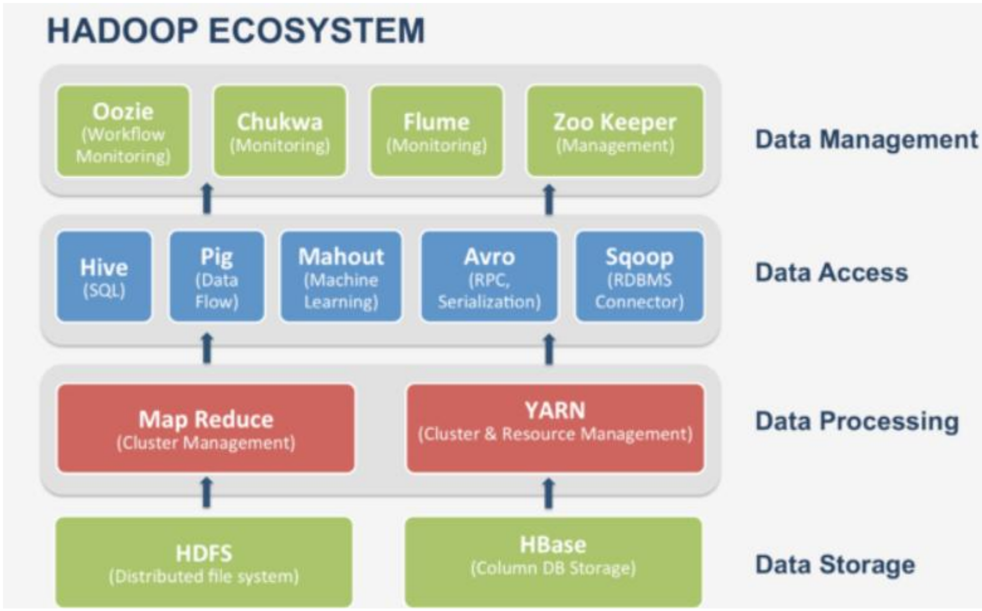

Figure 3.2.3. https://blogs.perficient.com/2022/08/10/hadoop-ecosystem-components/

The Hadoop ecosystem is like a digital zoo, housing various tools and technologies that work together to manage, access, process, and store big data. Think of it as a bustling city where different neighborhoods (components) collaborate to keep the data metropolis running smoothly. Here's a quick tour of this data-driven city:

- HDFS (Hadoop Distributed File System): The foundation of the city, providing reliable storage for massive amounts of data [32] [33].
- YARN (Yet Another Resource Negotiator): The city planner, managing resources and scheduling jobs across the cluster [32].
- MapReduce: The assembly line of the city, processing large datasets in parallel [32] [33].
- Hive: The data warehouse district, allowing SQL-like queries on large datasets [32] [34].
- Pig: The data transformation neighborhood, using a high-level language for creating MapReduce programs [32] [34].

[32] https://www.studysmarter.co.uk/explanations/computer-science/big-data/hadoop/

[33] https://cloud.google.com/learn/what-is-hadoop

[34] https://www.simpliaxis.com/resources/what-is-hadoop-ecosystem

- HBase: The real-time database quarter, offering quick read/write access to big datasets [32] [34]
- Sqoop: The import/export zone, transferring data between Hadoop and relational databases [33].
- Oozie: The workflow manager, coordinating the execution of Hadoop jobs [34].
- Zookeeper: The coordination center, managing and synchronizing the distributed services [34].

This ecosystem allows organizations to collect, store, process, and analyze vast amounts of data efficiently and cost-effectively, scaling from terabytes to petabytes with ease [32] [33].

Lesson 3.2.4. Tools for manipulating big data

The rapid growth of big data has necessitated the development of specialized tools for data manipulation and analysis. These tools are designed to handle massive datasets that traditional software cannot efficiently process. Here's an overview of some key tools used for manipulating big data, as described by Hal Varian in his paper "Big Data: New Tricks for Econometrics" [35]:

Google Name	Analog	Description
Google File System	Hadoop File System	A distributed file system that can stretch over many computers
MapReduce	Hadoop	A system for accessing and manipulating data in large datasets in parallel, using hundreds or thousands of machines
Sawzall	Pig	A general-purpose computer language that facilitates parallel data processing
Dremel, BigQuery	Hive, Drill, Impala	A tool that allows data queries to be written in a simplified form of Structured Query Language (SQL), capable of running queries on petabytes of data in seconds

These tools are designed to overcome the challenges posed by big data, such as the need for more powerful data manipulation capabilities, variable selection from a large number of potential predictors, and modeling complex relationships [35].

[35] https://www.sjsu.edu/people/tom.means/courses/bigdata/s1/Big-Data-New-Tricks-for-Econometrics---jep.28.2.3.pdf

For datasets that are too large for spreadsheets but not quite "big data," relational databases like MySQL can be useful. These databases use Structured Query Language (SQL) to store, manipulate, and retrieve data [35].

As datasets grow beyond several gigabytes or several million observations, "NoSQL" databases become necessary. These databases are designed to manage and query very large datasets efficiently [35].

It's worth noting that the field of big data analysis involves various overlapping disciplines. While statisticians often focus on inference, machine learning specialists are typically more concerned with prediction. Data scientists, a newer term, deal with both prediction and summarization, as well as data manipulation, visualization, and related tasks [35].

Lesson 3.2.5. Tools to process streaming data

In the world of big data, streaming solutions are like high-speed conveyor belts that process information in real-time. Three popular tools in this space are Apache Kafka Streams, Apache Flink, and Apache Storm. Let's explore these solutions and their unique characteristics:

Apache Kafka Streams:

- A lightweight library for building streaming applications, tightly integrated with Apache Kafka [36]
- Offers exactly-once processing guarantee, ensuring data integrity [36].
- Allows for stateful and stateless processing operations [36].
- Best suited for applications deeply integrated with Kafka, such as stream processing at moderate scale and real-time analytics [37].
- Primarily supports Java, which may limit its use for developers familiar with other languages [36].

Apache Flink:

- An open-source stream processing framework for high-performance, scalable, and fault-tolerant real-time analytics [36].
- Provides powerful event-time processing and watermarks for handling out-of-order events [36].
- Offers exactly-once processing semantics for improved data accuracy [36].
- Supports a wide range of operations including windowing, transformations, and aggregations
- Ideal for complex event processing, large-scale applications, and scenarios requiring advanced streaming capabilities [37].
- Has a steeper learning curve but provides rich features for skilled users [37].

Apache Storm:

- A distributed real-time computation system designed to process large volumes of high-velocity data [36]
- Provides real-time processing capabilities with low latency [36].
- Offers fault tolerance and at-least-once processing semantics [36].

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[36] https://www.designgurus.io/blog/kafka-streams-%20apache-flink-apache-storm
[37] https://www.redpanda.com/guides/event-stream-processing-kafka-streams-vs-flink

- Can process each tuple independently, useful for certain types of real-time computations [36].
- Supports multiple programming languages beyond Java [36].
- Does not natively support stateful operations, requiring additional manual work to handle state [36].

When choosing between these solutions:

- Kafka Streams is ideal for Kafka-centric environments and moderate-scale real-time analytics [37] [38].
- Apache Flink excels in high-throughput, low-latency scenarios, especially for large-scale streaming applications [37] [38].
- Apache Storm is suitable for real-time analytics, online machine learning, and distributed RPC [36]

Each solution has its strengths and trade-offs. Kafka Streams offers simplicity and tight Kafka integration, Flink provides advanced streaming capabilities and scalability, while Storm offers low-latency processing and language flexibility [36] [37] [38].The choice depends on specific use cases, existing infrastructure, and required features.

[38] https://bitrock.it/blog/technology/apache-flink-and-kafka-stream-a-comparative-analysis.html

Lesson 3.2.6. H2O: distributed machine learning

Figure 3.2.4. https://h2o.ai/platform/ai-cloud/make/h2o/

H2O is like a super-smart, lightning-fast brain for your computer that can crunch massive amounts of data and learn from it. Imagine a giant digital classroom where millions of pieces of information are being processed simultaneously by a team of genius robots - that's H2O in action!

At its core, H2O is an open-source, distributed machine learning platform that runs entirely in memory, making it incredibly fast [39]. It's designed to handle big data with ease, scaling effortlessly across multiple computers or servers. This means it can tackle problems that would make a regular computer throw up its hands in defeat.

H2O comes packed with a variety of machine learning algorithms, both supervised (where the computer learns from labeled data) and unsupervised (where it finds patterns in unlabeled data) [39]. These algorithms are like different tools in a Swiss Army knife, each designed for specific tasks:

- Gradient Boosting Machines: Great for predicting outcomes based on many factors
- Generalized Linear Models: Useful for understanding relationships between variables
- Deep Learning: Mimics the human brain to tackle complex problems
- Random Forest: Excellent for classification and regression tasks

[39] https://h2o.ai/platform/ai-cloud/make/h2o/

- K-means Clustering: Helps group similar data points together

One of H2O's superpowers is its AutoML feature [39]. This is like having an AI assistant that automatically tries out different machine learning models and tunes them to find the best performer for your specific problem. It's a real time-saver for data scientists and a game-changer for those new to machine learning.

H2O plays well with others, too. It supports multiple programming languages, including Python, R, Java, and Scala [39] [40]. This flexibility means that data scientists and developers can use the language they're most comfortable with, making H2O accessible to a wide range of users.

The platform also offers a web-based interface called H2O Flow [40]. This is like a digital whiteboard where you can interact with your data, build models, and visualize results without writing a single line of code. It's perfect for those who prefer a more visual approach to data analysis.

H2O isn't just fast; it's also smart about how it uses memory. It employs clever compression techniques to squeeze more data into available memory, allowing it to handle datasets up to 100 times larger than the physical memory available [39].

When it comes to deploying models into production, H2O makes it a breeze. It can export models as Java objects (POJOs) or model objects (MOJOs), which can be easily integrated into any Java environment [39]. This means your smart models can be quickly put to work in real-world applications.

H2O is used by thousands of organizations globally, from small startups to Fortune 500 companies [39]. Its speed, scalability, and ease of use make it a popular choice for tackling big data challenges across various industries.

In essence, H2O is like having a team of data science superheroes at your fingertips, ready to tackle any big data challenge you throw at them. Whether you're predicting customer behavior, detecting fraud, or analyzing complex scientific data, H2O provides the tools and horsepower to get the job done quickly and efficiently.

[40] https://big-data-test-infrastructure.ec.europa.eu/service-offering/h2oai_en

Lesson 3.2.7. Spark MLlib: fast machine learning

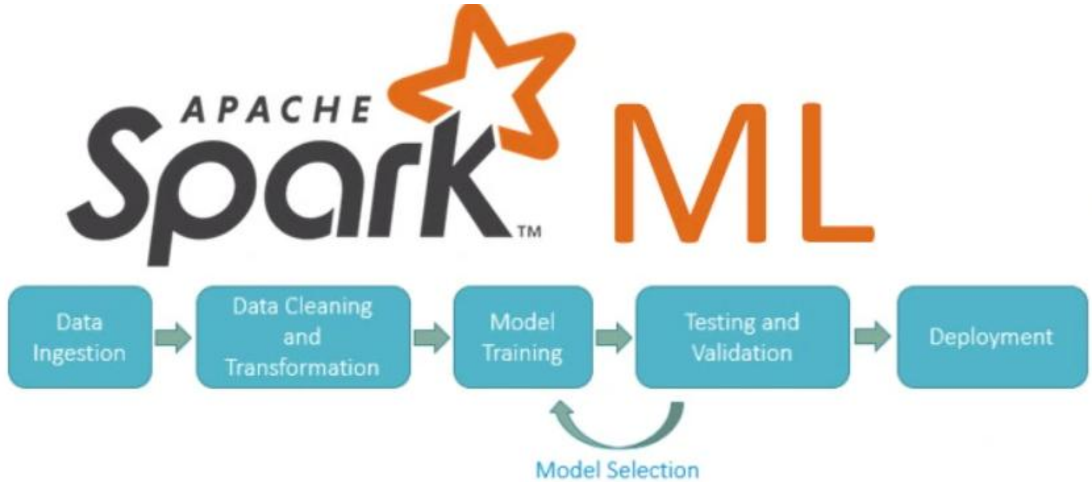

Figure 3.2.5. https://yurongfan.wordpress.com/2017/01/10/introduction-of-a-big-data-machine-learning-tool-sparkml/

Apache Spark MLlib is like a Swiss Army knife for big data machine learning. It's a powerful, versatile tool that can handle a wide range of machine learning tasks on massive datasets. Here's a quick overview of what MLlib brings to the table:

- Scalability: MLlib can crunch numbers across multiple computers, making it perfect for big data problems [41] [42][14][15]
- Language Support: It speaks multiple programming languages, including Java, Scala, Python, and R, so you can use your favorite tongue [43] [16]
- Algorithm Variety: MLlib comes packed with a buffet of machine learning algorithms:
  1. Classification: For sorting data into categories (like spam vs. not spam)
  2. Regression: For predicting numerical values (like house prices)
  3. Tree-based models: For making decisions based on multiple factors
  4. Recommendation systems: Think Netflix suggesting movies you might like
  5. Clustering: For grouping similar items together
  6. Topic modeling: For understanding themes in text data

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[41] https://www.linkedin.com/pulse/understanding-how-apache-mllib-empowers-scalable-machine-akash-jha-udl3f

[42] https://spark.apache.org/docs/latest/ml-guide

[43] https://spark.apache.org/mllib/

7. Market basket analysis: For finding patterns in shopping behavior [41 42].

MLlib integrates seamlessly with other Spark components, making it easy to build end-to-end machine learning pipelines. It's designed for speed and efficiency, leveraging Spark's distributed computing power to process data and train models quickly [41]. Whether you're a data scientist, a machine learning engineer, or just getting started with big data analytics, MLlib provides the tools you need to tackle complex machine learning tasks at scale.

Conclusions

Big data analytics is like a massive puzzle, and we've explored some powerful tools that help us solve it. Let's recap the key pieces:

- HDFS is our digital safety deposit box, keeping our data secure by making copies and spreading them around.
- MapReduce is like a team of helpers sorting through a mountain of Legos, breaking big jobs into smaller, manageable tasks.
- The Hadoop ecosystem is a bustling data city with different neighborhoods working together to manage, process, and store information.
- For streaming data, we have high-speed conveyor belts like Kafka Streams, Flink, and Storm, each with its own superpowers for real-time processing.
- H2O is like a team of genius robots, crunching numbers and learning from data at lightning speed.
- Spark MLlib is our Swiss Army knife for machine learning, packed with tools for all sorts of data analysis tasks.

These tools work together to help us make sense of the vast amounts of data in our digital world. They allow businesses and researchers to uncover insights, make predictions, and solve complex problems that were once thought impossible. As our data keeps growing, these tools will continue to evolve, opening up new possibilities for innovation and discovery in the exciting world of big data analytics.

Self-Assessment Quiz

Test your knowledge by taking the **TEST A** (https://open.ktu.edu/mod/quiz/view.php?id=10837) included in the 2nd Topic "Big data tools: Hadoop, Spark, H2O" of the MOOC "Big data" (https://open.ktu.edu/course/view.php?id=191).

TOPIC 3.3. Data processing with Python

After completing the topic learners will be able to use Python code for sequential and parallel data processing.

Overview of this topic

- Prepare Python environment
- Download data files
- Load and prepare data
- Check and select vars
- Pivot and calculate THI
- THI statistics and plots
- Export results to .html

Instructions for learning activities

1. See lesson's video;
2. Learn from slides & notes;
3. Try out Python code in Colab or ai-notebook.ktu.edu;
4. Take a quiz: Big Data TEST B;
5. For support use chatbot bellow or chat with the notes.

Topic content

Introduction

Google Colab serves as an ideal platform for data scientists and programmers to perform data processing tasks, such as analyzing the extensive World Air Quality Index (WAQI) database, which provides detailed pollution data for over 380 cities globally, enabling users to leverage Python libraries for insightful air quality analysis and visualization.

VIDEO 3.3.1. Data processing with Python [*duration 12:01 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/63722/course/section/2359/ASSIST_Big_Data_3_%28video%29.mp4

Lesson 3.3.1. Air quality data analysis

The World Air Quality Index (WAQI) project team provides a comprehensive dataset on air quality for about 380 major cities worldwide, updated three times daily since January 2015 [44] [1]. This dataset is like a giant digital logbook of the air we breathe, covering cities across the globe.

The data for each city is based on the average (median) of several air quality monitoring stations, similar to taking the middle value from multiple thermometers in different parts of a city to get an overall temperature reading. The dataset includes a range of air pollutant measurements, including:

- Particulate matter (PM2.5 and PM10)
- Nitrogen dioxide (NO2)
- Ozone (O3)
- Sulfur dioxide (SO2)
- Carbon monoxide (CO)

It also provides meteorological data like temperature, humidity, and wind information [44].

For each of these pollutants and weather factors, the dataset offers minimum, maximum, median, and standard deviation values. This is like getting a report card for the air, showing the best, worst, typical, and how much the air quality varies each day.

The data is particularly useful for researchers and policymakers. It's like having a health check-up for our cities' air, allowing us to see patterns and make informed decisions about improving air quality.

One interesting application of this data is calculating the Temperature Humidity Index (THI). The THI is a measure of how comfortable (or uncomfortable) the weather feels to people and animals, combining temperature and humidity. It's like a "feels like" temperature that takes humidity into account. The formula for THI is:

$$\boldsymbol{THI = 0.8 \times Temperature + Humidity \times (Temperature - 14.4) + 46.4}$$

[44] https://aqicn.org/data-platform/covid19/

This index helps us understand not just how hot it is, but how the combination of heat and humidity affects comfort and potentially health [44].

The WAQI dataset is part of a larger movement towards open air quality data. For example, the United Nations Environment Programme (UNEP), together with UN-Habitat and IQAir, launched the world's largest air quality data platform in 2020 [45].

This platform brings together real-time air pollution data from over 4,000 contributors worldwide, including citizens, communities, governments, and private sector entities.

These initiatives aim to empower people with knowledge about the air they breathe. It's like giving everyone a personal air quality monitor, helping them make informed decisions about their health and encouraging governments to take action for cleaner air [45].

[45] https://www.unep.org/news-and-stories/press-release/worlds-largest-platform-air-quality-data-launched-tenth-world-urban

Lesson 3.3.2. Required Python packages

Python offers a variety of packages that can be used for data processing and analysis, much like a toolbox filled with specialized tools for different tasks. For the air quality data analysis project, several key packages are required:

- os: Provides a way to use operating system dependent functionality, like working with file paths.
- re: Offers support for regular expressions, useful for pattern matching in strings.
- requests: Allows sending HTTP requests easily, like fetching data from web APIs.
- logging: Helps in tracking events that happen when the software runs.
- calplot: Enables creation of calendar heatmaps, visualizing data over time.
- dask.dataframe: Provides a large-scale dataframe implementation, like a supercharged version of pandas for big data.
- multiprocessing: Supports spawning processes using an API similar to the threading module.
- dask.multiprocessing: Offers a dask-specific implementation of multiprocessing.
- tqdm: Adds a progress bar to loops or long-running operations.
- itertools: Provides a set of fast, memory efficient tools for handling iterators.
- eu_country_codes: A custom module (likely) containing country codes for European Union members.

It's important to note that some users have reported compatibility issues with Python 3.11.9 and certain versions of dask [46]. If you encounter errors, you may need to adjust your Python or package versions.

[46] https://github.com/dask/dask/issues/11038

Self-Assessment Quiz

Test your knowledge by taking the **TEST B** (https://open.ktu.edu/mod/quiz/view.php?id=10925) included in the 3rd Topic “Data processing with Python language” of the MOOC “Big data” (https://open.ktu.edu/course/view.php?id=191).

TOPIC 3.4. Data processing with R

After completing the topic learners will be able to use R code for sequential and parallel data processing.

Overview of this topic

- Prepare R environment
- Download data files
- Load and prepare data
- Check and select vars
- Pivot and calculate THI
- THI statistics and plots
- Export results to .html

Instructions for learning activities

1. See lesson's video;
2. Learn from slides & notes;
3. Try out R code in Colab or ai-notebook.ktu.edu;
4. Take a quiz: Big Data TEST C;
5. For support use chatbot bellow or chat with the notes.

Topic content

Introduction

Google Colab offers a free cloud-based platform for R programming enthusiasts to explore the World Air Quality Index (WAQI) dataset, which provides detailed insights into air pollution and weather conditions across approximately 380 major cities globally, using a suite of essential R libraries for data manipulation, visualization, and interaction with web APIs.

VIDEO 3.4.1. Data processing with R [*duration 19:33 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/63722/course/section/2358/ASSIST_Big_Data_4_%28video%29.mp4

Lesson 3.4.1. Air quality analysis

The World Air Quality Index (WAQI) dataset is like a giant health report card for the air in cities around the world. Imagine if you could take the temperature of the air, not just for heat, but for all sorts of pollutants that can make us sick. That's what this dataset does for about 380 major cities, updating three times every day since 2015 [47].

To get this information, scientists use special air quality monitoring stations scattered around each city. It's like having a bunch of super-sensitive noses sniffing the air all the time. They take all these "sniffs" and find the middle value (median) to give us a good idea of what the air is like overall in that city [47].

The dataset looks at several types of air pollutants:

- Particulate matter (PM2.5 and PM10): Think of these as tiny bits of dust or smoke floating in the air.
- Nitrogen dioxide (NO2): This is like the exhaust from cars and factories.
- Ozone (O3): Not the good ozone that protects us from the sun, but a harmful version closer to the ground.
- Sulfur dioxide (SO2): This often comes from burning fossil fuels.
- Carbon monoxide (CO): A dangerous gas that can come from car exhaust or faulty heaters.

The dataset also includes weather information like temperature, humidity, and wind [47]. It's like getting a full weather report along with an air quality check.For each of these pollutants and weather factors, the dataset gives us the lowest (minimum), highest (maximum), typical (median), and how much it varies (standard deviation) each day. It's like knowing not just how bad the air can get, but also how good it can be and what's normal for that city [47].

One cool thing scientists can do with this data is calculate something called the Temperature Humidity Index (THI). The THI is like a "feels like" temperature that takes into account both how hot it is and how humid it is. This is important because sometimes it can feel much hotter than the thermometer says if there's a lot of moisture in the air. The formula for THI looks like this:

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[47] https://aqicn.org/data-platform/covid19/

$$THI = 0.8 \times Temperature + Humidity \times (Temperature - 14.4) + 46.4$$

This helps us understand how comfortable or uncomfortable the weather really feels to people and animals [47].

The WAQI dataset is part of a bigger movement to make air quality information available to everyone. For example, the United Nations Environment Programme (UNEP) worked with other organizations to create the world's largest air quality data platform in 2020. This platform collects real-time air pollution data from over 4,000 different sources all over the world, including regular people, communities, governments, and businesses [48].

The goal of all this data collection is to give people the power to know what's in the air they're breathing. It's like having a personal air quality detector that you can check anytime. This information can help people make better decisions about their health, like when it might be better to stay indoors or wear a mask. It also puts pressure on governments to take action to make the air cleaner for everyone [48].

[48] https://aqicn.org/data-platform/register/

Lesson 3.4.2. Required R libraries

R libraries are like specialized toolkits that extend R's capabilities, allowing users to perform specific tasks more efficiently. For this project, we'll be using several key libraries. Here's a breakdown of each library and its primary function:

1 dplyr: The Swiss Army knife of data manipulation in R. It provides a set of tools for efficiently manipulating datasets in R, using an easy-to-understand syntax [49].
2 tidyr: Works hand-in-hand with dplyr to create tidy data, where each variable is a column, each observation is a row, and each type of observational unit is a table [49].
3 ggplot2: The go-to library for creating elegant and complex plots in R. It's based on the grammar of graphics, providing a powerful model of graphics that makes it easy to produce complex multi-layered graphics [50].
4 httr: This library is useful for making HTTP requests in R, allowing you to interact with web APIs and download data from the internet.
5 data.table: A high-performance version of R's standard data.frame with syntax and feature enhancements for ease of use, convenience and programming speed [51].
6 dtplyr: Provides a data.table backend for dplyr, allowing you to write dplyr code that is automatically translated to equivalent data.table code [51].
7 xts: Provides tools for working with time series data in R, extending R's ts objects.
8 eurostat: A library that allows easy access to the Eurostat database, providing functions to search for, download and manipulate Eurostat data.
9 pals: Provides color palettes, useful for creating visually appealing and informative plots.
10 pbapply: A package that adds progress bars to R's *apply functions, useful for tracking the progress of long-running operations.
11 doParallel: Provides a parallel backend for the foreach package, allowing you to parallelize your code and take advantage of multiple cores on your machine.

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[49] https://stackoverflow.com/questions/68853386/how-to-ggplot-using-dtplyr-data-table-without-converting-it-into-dataframe-or

[50] https://www.datasciencemeta.com/rpackages

[51] https://www.appsilon.com/post/r-dtplyr

These libraries work together to provide a powerful toolkit for data manipulation, visualization, and analysis. By combining them, you can efficiently process large datasets, create informative visualizations, and perform complex analyses.

Self-Assessment Quiz

Test your knowledge by taking the **TEST C** (https://open.ktu.edu/mod/quiz/view.php?id=10924) included in the 4th Topic “Data processing with R programming” of the MOOC “Big data” (https://open.ktu.edu/mod/quiz/view.php?id=10925).

TOPIC 3.5. Time-series forecasting

After completing the topic learners will be able to obtain forecast using multivariate Prophet model.

Overview of this topic

- Overview of time-series forecasting methods
- Importance of backtesting in evaluating forecasting models
- Distinction between univariate and multivariate forecasting models
- Consideration of forecasting errors in model evaluation
- Utilization of different error metrics for model comparison
- Benefits and features of Prophet forecasting model
- Components and characteristics of Prophet model for accurate forecasts

Instructions for learning activities

1. Learn from slides & notes;
2. Try R code in posit.cloud or RStudio;
3. Take a quiz: Big Data TEST D (it involves Topic #7 too);
4. For support use chatbot bellow or chat with the notes.

Topic content

Introduction

Time-series forecasting involves predicting future data points based on historical trends and patterns, utilizing techniques like backtesting to evaluate model performance, and distinguishing between univariate and multivariate approaches to account for varying complexities and data dependencies.

Lesson 3.5.1. Backtesting in time-series forecasting

Backtesting is a critical technique in time series forecasting used to evaluate the performance of predictive models on historical data. It simulates how a model would have performed if it had been used in the past, providing insights into its potential future performance [52] [53]. Unlike traditional cross-validation methods used in machine learning, backtesting respects the temporal order of observations, which is crucial for time series data [54].

Key aspects of backtesting in forecasting include:

1. Data Splitting: The historical data is divided into training and validation (or test) sets. The training set is used to build the model, while the validation set simulates future, unseen data [52] [53].
2. Temporal Order: Backtesting maintains the chronological sequence of data points, ensuring that only past information is used to predict future values [54].
3. Performance Metrics: Common metrics used in backtesting include Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE) [53]. These metrics quantify the difference between forecasted and actual values.
4. Multiple Evaluation Periods: To increase robustness, backtesting often involves multiple train-test splits or a rolling window approach [54].

Backtesting methods:

1. Train-Test Split: A simple approach where the data is split into a single training and testing period [54].
2. Multiple Train-Test Splits: This method creates multiple training and testing periods, providing a more comprehensive evaluation [54].
3. Walk-Forward Validation: Also known as rolling-window backtesting, this approach incrementally increases the training set while testing on subsequent periods. It closely mimics real-world forecasting scenarios [54].

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[52] https://towardsdatascience.com/why-backtesting-matters-and-how-to-do-it-right-731fb9624a

[53] https://blog.exploratory.io/a-gentle-introduction-to-backtesting-for-evaluating-the-prophet-forecasting-models-66c132adc37c

[54] https://machinelearningmastery.com/backtest-machine-learning-models-time-series-forecasting/

Mathematically, the walk-forward validation can be expressed as:

For each time step tt in the validation period:

1 Train the model on data from [1, t−1]

2 Make a forecast for time t

3 Compute the error $e_t = y_t - \hat{y}_t$

4 Aggregate errors to compute performance metrics

When implementing backtesting, it's crucial to avoid look-ahead bias, where future information inadvertently influences the model training or parameter selection [52]. This can lead to overly optimistic performance estimates.

Backtesting is particularly important in financial forecasting, where it's used to evaluate trading strategies and risk models [52]. However, it's equally applicable in other domains such as demand forecasting, weather prediction, and resource planning.

While backtesting is a powerful tool, it's important to note that past performance doesn't guarantee future results. Economic conditions, market dynamics, and other factors can change, potentially affecting model performance. Therefore, backtesting should be used in conjunction with domain expertise and forward-looking analysis for comprehensive model evaluation [52] [53].

Lesson 3.5.2. Scale-dependent vs relative errors

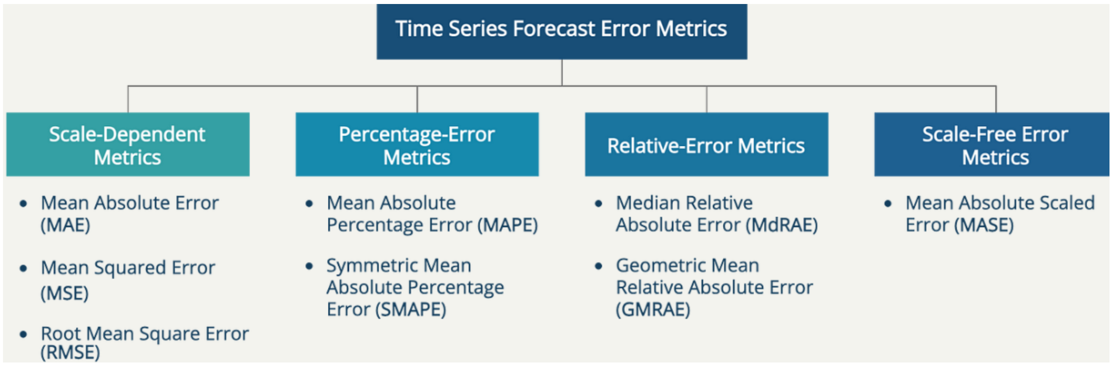

Figure 3.5.1. *https://towardsdatascience.com/time-series-forecast-error-metrics-you-should-know-cc88b8c67f27*

Time series forecasting error metrics can be broadly categorized into scale-dependent and scale-independent measures. Scale-dependent errors are useful for comparing forecasts within a single series, while relative errors allow for comparisons across different series. Here's an overview of key formulas for both types:

Scale-dependent error measures:

- Mean Absolute Error (MAE):

  where *et = yt − y^t* (actual value minus forecast)
- Root Mean Squared Error (RMSE):

  $$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2}$$
- Mean Squared Error (MSE):

  $$\text{MSE} = \frac{1}{n}\sum_{t=1}^{n} e_t^2$$

Relative error measures:

- Mean Absolute Percentage Error (MAPE):

  $$\text{MAPE} = \frac{100\%}{n}\sum_{t=1}^{n}\left|\frac{e_t}{y_t}\right|$$
- Symmetric Mean Absolute Percentage Error (sMAPE):

  $$\text{sMAPE} = \frac{200\%}{n}\sum_{t=1}^{n}\frac{|e_t|}{|y_t|+|\hat{y}_t|}$$

- Mean Absolute Scaled Error (MASE):

$$\text{MASE} = \frac{\text{MAE}}{\frac{1}{n-1}\sum_{t=2}^{n}|y_t - y_{t-1}|}$$

- For seasonal data with period m:

$$\text{MASE} = \frac{\text{MAE}}{\frac{1}{n-m}\sum_{t=m+1}^{n}|y_t - y_{t-m}|}$$

- Relative Mean Absolute Error (RMAE):

$$\text{RMAE} = \frac{\text{MAE}}{\text{MAE}_{\text{reference}}}$$

where $\text{MAE}_{\text{reference}}$ is the MAE of a benchmark method (often naïve forecast)

Scale-dependent errors like MAE and RMSE are easier to interpret but cannot be used to compare forecasts across different series [55]. Relative errors address this limitation but can have issues with zero values or small denominators [56] [57].

The Mean Absolute Scaled Error (MASE) was proposed as a generally applicable measure that avoids the problems of other relative error metrics [57]. It scales the errors based on the in-sample MAE from a naïve forecast method, making it suitable for comparing forecast accuracy between series and handling intermittent demand [57] [58].

When selecting an error metric, consider the specific characteristics of your data and forecasting goals. For instance, RMSE gives higher weight to large errors, which may be desirable in some contexts but not others [55]. Additionally, some metrics like MAPE can favor underprediction, while others like sMAPE aim to be more symmetric [56] [59].

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[55] https://otexts.com/fpp2/accuracy.html

[56] https://deep-and-shallow.com/2020/10/01/forecast-error-measures-scaled-relative-and-other-errors/

[57] https://robjhyndman.com/papers/foresight.pdf

[58] https://openforecast.org/adam/errorMeasures.html

[59] https://towardsdatascience.com/time-series-forecast-error-metrics-you-should-know-cc88b8c67f27

Lesson 3.5.3. Prophet: forecasting framework

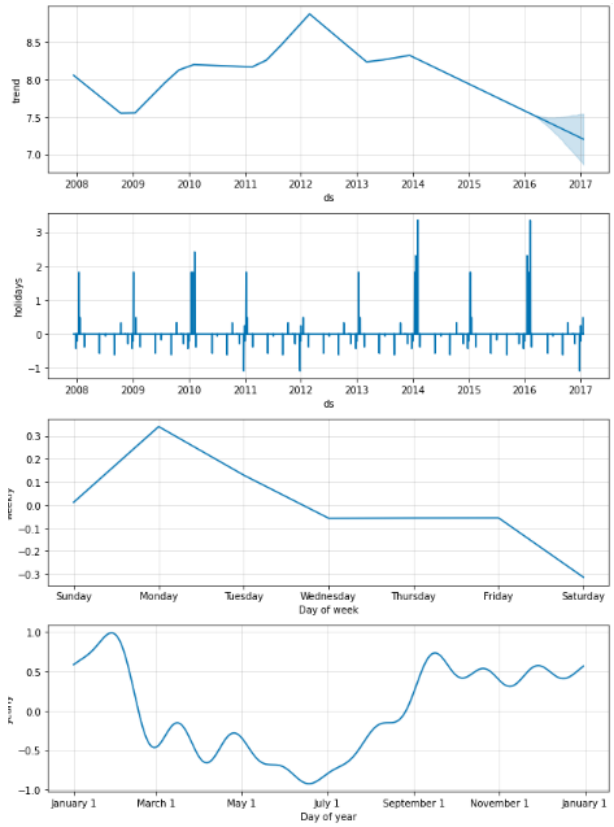

Figure 3.5.2. https://facebook.github.io/prophet/docs/seasonality,_holiday_effects,_and_regressors.html

Prophet is a powerful forecasting model that incorporates several key features to handle complex time series data. Here's an overview of its main characteristics:

- Decomposable time series model: Based on the work of Harvey and Peters (1990), Prophet decomposes time series into three main components [60] [9]:
  1. Growth (trend)
  2. Seasonality
  3. Holidays
- Additive model structure: The time series is modeled as a sum of these components, allowing for flexible and interpretable forecasts [61].

[60] https://forecasting-encyclopedia.com/theory.html

[61] https://facebook.github.io/prophet/static/prophet_paper_20170113.pdf

- Non-linear trend modeling: Can capture complex, non-linear trends in the data [62].
- Multiple seasonality handling: Accommodates yearly, weekly, and daily seasonality patterns [62].
- Holiday effects: Incorporates the impact of holidays and special events on the time series [61].
- Optimal data characteristics:
    - Works best with daily data
    - Requires at least one year of historical data for accurate seasonality modeling [62].
- Robustness:
    - Handles missing data effectively
    - Adapts to shifts in the underlying trend
    - Resilient to large outliers in the dataset [62].
- Automatic forecasting: Provides reasonable forecasts on messy data with minimal manual intervention [62].
- Tunable parameters: Allows users to adjust forecasts using interpretable parameters, incorporating domain knowledge [62].

This combination of features makes Prophet particularly suitable for forecasting time series with strong seasonal patterns, multiple periodicities, and irregular events, while being robust to common data quality issues.

[62] https://facebook.github.io/prophet/

Lesson 3.5.4. Univariate vs multivariate model

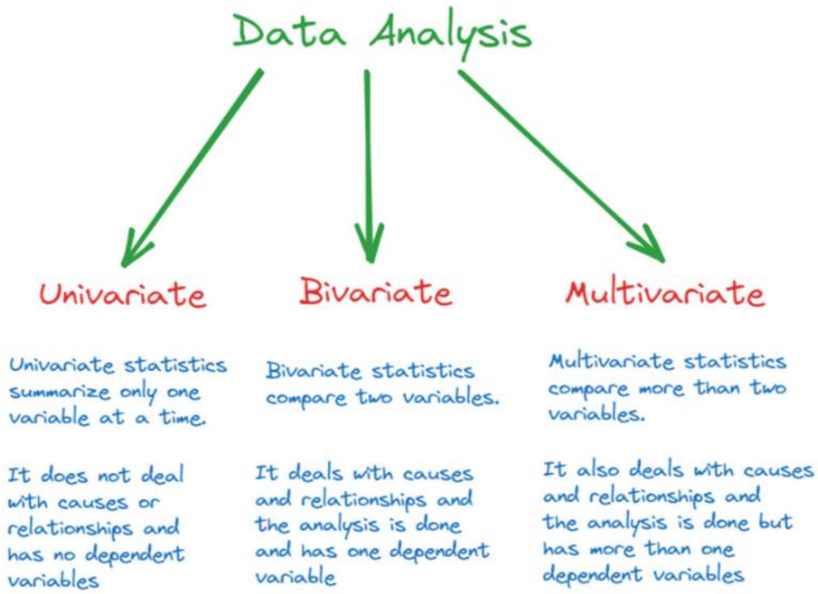

Figure 3.5.3. https://facebook.github.io/prophet/docs/seasonality,_holiday_effects,_and_regressors.html

Time series forecasting models can be broadly categorized into univariate and multivariate approaches based on the number of variables used for prediction:

- Univariate models: These models rely solely on the historical values of the target variable (Y) to make predictions. Univariate forecasting is a simpler approach that assumes the future values of Y can be predicted using only its past values, without considering any external factors [63] [64]
- Multivariate models: These models incorporate additional explanatory variables (X) along with the historical values of the target variable (Y) to make predictions. Multivariate forecasting takes into account the relationships and dependencies between the target variable and other relevant factors, potentially leading to more accurate predictions [65] [64].

When using Facebook's Prophet library for time series forecasting, the modeling process differs slightly between univariate and multivariate approaches:

[63] https://towardsdatascience.com/time-series-forecasting-with-facebooks-prophet-in-10-minutes-958bd1caff3f
[64] https://www.linkedin.com/pulse/time-series-forecasting-univariate-vs-multivariate-rohan-anand-mvgrf
[65] https://stackoverflow.com/questions/54544285/is-it-possible-to-do-multivariate-multi-step-forecasting-using-fb-prophet

Univariate modeling with Prophet:

1 Create a Prophet model object using the 'prophet ()' function.
2 Generate future dates for forecasting using the 'make_future_dataframe ()' function.
3 Make predictions using the 'predict ()' function on the future dataframe.

Multivariate modeling with Prophet:'

1 Create a Prophet model object using the 'prophet ()' function.
2 Add external regressors (explanatory variables) to the model using the 'add_regressor ()' function for each additional variable.
3 Fit the model to the historical data using the 'fit ()' function.
4 Generate future dates for forecasting using the 'make_future_dataframe ()' function, including values for the external regressors.
5 Make predictions using the 'predict ()' function on the future dataframe.

The choice between univariate and multivariate approaches depends on the specific characteristics of the data and the forecasting goals. Univariate models are simpler and computationally efficient but may not capture the full complexity of the problem. Multivariate models can potentially provide more accurate predictions by considering additional relevant factors but require more data and computational resources [64].

It's important to note that while Prophet is primarily designed for univariate forecasting, it can incorporate additional regressors to enable multivariate modeling. However, the library may not be as flexible or comprehensive as other dedicated multivariate forecasting techniques like Vector Autoregression (VAR) or machine learning-based approaches [65] [66].

When selecting between univariate and multivariate forecasting models, consider factors such as the availability and relevance of external variables, the complexity of the problem, and the interpretability and computational requirements of the chosen approach.

[66] https://forecastegy.com/posts/multiple-time-series-forecasting-with-prophet-in-python/

Lesson 3.5.5. Ex-post vs ex-ante forecasting

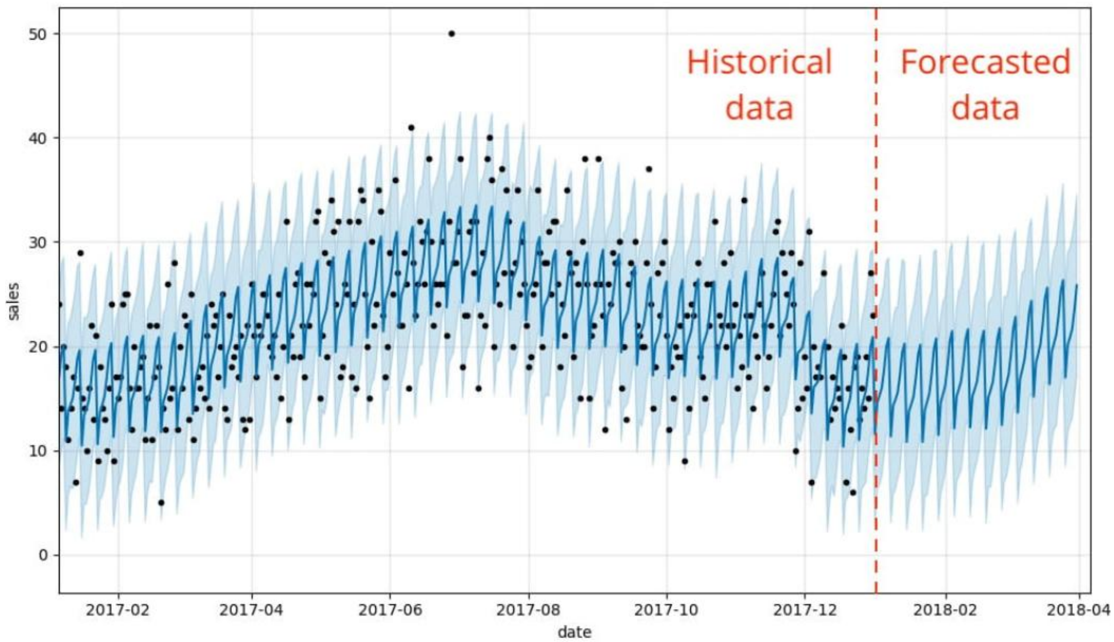

Figure 3.5.4. https://www.databricks.com/blog/2020/01/27/time-series-forecasting-prophet-spark.html

Multivariate forecasting models present unique challenges when predicting future values of the target variable *Y*, as they require knowledge of future values for the explanatory variables *X*. This requirement leads to important considerations in model development and evaluation:

Availability of future X values:

- YES: Rare in practice, but ideal for accurate multivariate forecasting.
- NO: More common scenario, requiring additional steps to estimate future X values.

Approaches for handling unknown future X values:

1. Univariate forecasting of X variables
2. Scenario analysis with assumed X values
3. Simultaneous forecasting of Y and X using vector autoregression (VAR) models
4. Use of leading indicators or proxy variables with known future values

Types of testing errors in multivariate forecasting:

1. EX-POST errors:

- Use actual future X values in the model
- Tend to be optimistic, as they don't account for X prediction errors
- Useful for assessing the model's theoretical performance
- Formula: $e_{t,EX-POST}=Yt-f(Xt,\theta)$

  where Y_t is the actual value, X_t are the actual explanatory variables, and θ are the model parameters

2 EX-ANTE errors:

- Use forecasted X values in the model
- More realistic, as they incorporate uncertainty in X predictions
- Better represent real-world forecasting scenarios
- Formula: $e\ t,EX-ANTE=Yt-f(X\hat{}t,\theta)$

  where $X\hat{}_t$ are the forecasted explanatory variables

Implications for model evaluation:

- EX-POST evaluation may overestimate model performance
- EX-ANTE evaluation provides a more conservative and realistic assessment
- Comparison of EX-POST and EX-ANTE errors can quantify the impact of X variable uncertainty

Strategies for improving multivariate forecasts:

1. Develop accurate univariate models for X variables
2. Incorporate uncertainty in X forecasts using probabilistic methods
3. Use ensemble methods combining multiple forecasting approaches
4. Regularly update and retrain models as new data becomes available

When developing and evaluating multivariate forecasting models, it's crucial to consider both EX-POST and EX-ANTE scenarios to gain a comprehensive understanding of model performance and potential real-world applicability [67] [68]. The choice between these approaches depends on the specific forecasting goals, data availability, and the level of uncertainty acceptable in the predictions.

[67] https://homepage.univie.ac.at/robert.kunst/prognos4.pdf

[68] https://www.sas.upenn.edu/~fdiebold/Teaching221/Fcst4Solns.pdf

Conclusions

Time series forecasting is a complex field that encompasses various techniques and considerations. Here's a synthesis of the key points covered in the previous sections:

Forecasting approaches:

1) Univariate models: Use only historical values of the target variable
2) Multivariate models: Incorporate additional explanatory variables

Backtesting: Essential for model evaluation, respecting temporal order of data:

- Methods: Train-test split, multiple splits, walk-forward validation
- Avoids look-ahead bias

Error metrics:

- Scale-dependent: MAE, RMSE, MSE
- Relative: MAPE, sMAPE, MASE, RMAE
- Choice depends on data characteristics and forecasting goals

Ex-post vs Ex-ante forecasting:

- Ex-post: Uses actual future values of explanatory variables (optimistic)
- Ex-ante: Uses forecasted values of explanatory variables (more realistic)

Prophet framework:

- Decomposable model: growth, seasonality, holidays
- Additive structure
- Handles non-linear trends and multiple seasonalities
- Robust to missing data, outliers, and trend shifts

These concepts form a comprehensive toolkit for time series forecasting, enabling practitioners to select appropriate methods, evaluate model performance, and make informed decisions based on the specific characteristics of their data and forecasting objectives [69] [70] [71] [72].

[69] https://writingcenter.unc.edu/tips-and-tools/conclusions/

[70] https://newunderthesunblog.wordpress.com/2015/06/30/writing-the-discussionconclusion-section/

[71] https://libguides.usc.edu/writingguide/conclusion

[72] https://www.linkedin.com/advice/3/how-can-you-write-compelling-conclusion-scientific-rnref

Self-Assessment Quiz

Test your knowledge by taking the **TEST D** (https://open.ktu.edu/mod/quiz/view.php?id=12642) included in the 5th Topic "Time-series analysis and forecasting" of the MOOC "Big data" (https://open.ktu.edu/mod/quiz/view.php?id=10924).

TOPIC 3.6. Low-code framework for visuals with Python

After completing the topic learners will be able to create a dashboard with Python Gradio library.

Overview of this topic

- Code represents a simple dashboard for air quality data analysis and visualization.
- Developed interactive interfaces allows users to explore air quality analysis results.
- Python Gradio Blocks allows for flexible layouts in the dashboard.
- Specific plot functions for selected city and years in the dashboard.
- Enhanced user experience by dropdowns, checkboxes, and radio buttons.

Instructions for learning activities

1. See lesson's video;
2. Learn from slides & notes;
3. Try out Python code in Colab or ai-notebook.ktu.edu;
4. For support use chatbot bellow or chat with the notes.

Topic content

Introduction

Python's versatility in creating interactive dashboards is further enhanced by Gradio, a library that simplifies building web interfaces for data visualization and machine learning models. Gradio's features, such as the Blocks API for layout design, interactive components, and real-time updates, make it an ideal tool for developing user-friendly applications like air quality data dashboards, seamlessly integrating with libraries like Pandas, Matplotlib, and Plotly to offer dynamic and informative visualizations.

VIDEO 3.6.1. Dashboard with Python [*duration 9:31 minutes, created by the course authors*]: https://open.ktu.edu/pluginfile.php/63722/course/section/2362/ASSIST_Big_Data_6_%28video%29.mp4

Lesson 3.6.1. Air quality analysis with Gradio

Gradio is a powerful Python library for creating interactive web interfaces for machine learning models and data visualization dashboards. It simplifies the process of building user-friendly applications without requiring extensive web development knowledge. In the context of creating dashboards for air quality data analysis, Gradio offers several key features and components:

1. Blocks API: Gradio's Blocks API allows for flexible layout design, enabling developers to create complex, multi-component dashboards. This is particularly useful for air quality data visualization, where multiple plots and user inputs may be required [73].
2. Interactive Components: Gradio provides a range of interactive elements such as dropdowns, checkboxes, and radio buttons. These components enhance user experience by allowing dynamic selection of cities, years, or other parameters for air quality analysis [73].
3. Real-time Updates: Gradio supports real-time updates of visualizations based on user inputs. This feature is crucial for air quality dashboards, where users may want to explore different scenarios or time periods [73].
4. Integration with Data Analysis Libraries: Gradio seamlessly integrates with popular data analysis and visualization libraries like Pandas, Matplotlib, and Plotly. This integration allows for efficient data manipulation and creation of various chart types for air quality data representation [74].
5. Custom Plot Functions: Developers can define specific plot functions for selected cities and years, which can be easily incorporated into the Gradio interface. These functions can leverage libraries like Matplotlib or Plotly to create tailored visualizations for air quality metrics [74].
6. Data Loading and Preprocessing: Within the Gradio application, data can be loaded and preprocessed using Pandas. For air quality data, this might involve reading CSV files, filtering data for specific cities or time periods, and calculating relevant statistics [75].
7. Markdown and HTML Support: Gradio allows the inclusion of formatted text and HTML elements, which can be used to add explanations, titles, or additional context to the air quality dashboard [74].

[73] https://www.gradio.app/guides/creating-a-dashboard-from-bigquery-data
[74] https://docs.kanaries.net/pygwalker/tutorials/use-pygwalker-in-gradio
[75] https://www.gradio.app/guides/creating-a-dashboard-from-supabase-data

8. Deployment Options: Gradio applications can be easily shared and deployed, making it simple to distribute air quality dashboards to stakeholders or the public [73].

Here's a simplified example of how a Gradio dashboard for air quality data might be structured:

```python
import gradio as gr
import pandas as pd
import plotly.express as px

# Load and preprocess data
df = pd.read_csv("air_quality_data.csv")

def plot_air_quality(city, year, pollutants):
  filtered_df = df[(df['city'] == city) & (df['year'] == year)]
  fig = px.line(filtered_df, x='date', y=pollutants, title=f"Air Quality in {city} ({year})")
  return fig

with gr.Blocks() as demo:
  gr.Markdown("# Air Quality Dashboard")
  with gr.Row():
    city = gr.Dropdown(choices=df['city'].unique(), label="City")
    year = gr.Dropdown(choices=df['year'].unique(), label="Year")
  pollutants = gr.CheckboxGroup(choices=['PM2.5', 'PM10', 'NO2', 'O3'], label="Pollutants")
  plot = gr.Plot()

  gr.interface(
    fn=plot_air_quality,
    inputs=[city, year, pollutants],
    outputs=plot
  )

demo.launch()
```

This example demonstrates how Gradio can be used to create an interactive dashboard for air quality data. It includes dropdown menus for city and year selection, checkboxes for pollutant selection, and a dynamic plot that updates based on user inputs. The 'plot_air_quality' function uses Plotly Express to create a line chart of selected pollutants over time for the chosen city and year [73 74 75]. By leveraging Gradio's capabilities, developers can create sophisticated, interactive dashboards that allow users to explore air quality data in an intuitive and informative manner.

Lesson 3.6.2. Gradio for serving ML models

Gradio provides a streamlined process for sharing and testing machine learning models. The key steps in this process are:

1. Interface Definition:
   - The researcher defines input and output interface types
   - Launches the interface inline or in a new browser tab
2. Interface Launch:
   - The defined interface is launched
   - Optionally, a public link is generated for remote access
3. User Interaction:
   - Users can manipulate the model inputs naturally
   - Examples include cropping or obscuring parts of images
4. Computation:
   - All model computation is performed on the host machine
   - The host is the computer that initially called Gradio
5. Remote Collaboration:
   - The public link allows remote collaborators to input their own data
   - Enables wider testing and sharing of the model

This workflow enables machine learning researchers to quickly create interactive demos of their models without extensive web development knowledge. The ability to generate public links facilitates easy sharing and remote testing, while keeping computation on the host machine ensures security and control over the model [76].

[76] https://www.gradio.app/guides/quickstart

Lesson 3.6.3. Creating diagrams: gradio.Plot

Gradio's Plot component provides a versatile solution for displaying various types of plots within a Gradio interface. This component supports multiple popular Python plotting libraries, offering flexibility in visualization techniques. Here's an overview of the key features and usage of the gradio.Plot component:

Supported plotting libraries:

- Matplotlib
- Plotly
- Bokeh
- Seaborn (via Matplotlib)

Input handling:

- The Plot component does not accept direct user input

Output expectations:

- Matplotlib: matplotlib.figure.Figure object
- Plotly: plotly.graph_objects._figure.Figure object
- Bokeh: Dictionary in json_item format

Usage in Gradio apps:

- Can be used to display static or interactive plots
- Allows for dynamic updates based on user interactions with other components
- Supports various plot types including line charts, scatter plots, bar graphs, and more

Example usage:

```python
import gradio as gr
import matplotlib.pyplot as plt

def create_plot(x, y):
    fig, ax = plt.subplots()
    ax.plot(x, y)
```

```
    return fig

demo = gr.Interface(fn=create_plot, inputs=["text", "text"], outputs="plot")
demo.launch()
```

This component enables developers to seamlessly integrate sophisticated data visualizations into their Gradio applications, enhancing the overall user experience and data presentation capabilities [77] [78]

[77] https://www.gradio.app/main/docs/gradio/plot

[78] https://www.gradio.app/docs/gradio/plot

Lesson. 3.6.4. Air quality dashboard explained

This section demonstrates the implementation of a Gradio dashboard for visualizing Temperature Humidity Index (THI) data. The code showcases key features of Gradio and data manipulation techniques using pandas. Here's a breakdown of the main components:

Component	Description
Data Preparation	Extracts unique cities and years from the dataset
Time Series Controls	Defines buttons for time range selection in plots
Plot Function	Creates various plot types based on user selections
Gradio Interface	Designs the dashboard layout and interactivity

The 'make_plot' function is central to the dashboard's functionality, generating different visualizations based on user inputs:

- Calendar Plot: Uses the 'calplot' library to create a heatmap-style calendar visualization of THI values.
- Monthly Box Plot: Displays THI distribution by month using Plotly Express.
- Weekday Box Plot: Shows THI distribution by day of the week.
- Time Series Plot: Creates a line plot of THI over time with interactive range selection.

The Gradio interface is constructed using the 'Blocks' API, which allows for a flexible layout:

```python
with gr.Blocks() as demo:
    citySelect = gr.Dropdown(myCities, label="City:", value="Bucharest")
    yearSelect = gr.CheckboxGroup(myYears, label="Years:", value=myYears)
    plotSelect = gr.Radio(label="Plot type:", choices=['calplot', 'by month', 'by weekday', 'time series'],
value='calplot')
    plotVisual = gr.Plot(show_label=False, container=False)
```

This setup creates dropdown menus for city selection, checkboxes for year selection, and radio buttons for plot type selection. The 'change' method is used to update the plot when user selections are modified:

```python
citySelect.change(make_plot, inputs=[citySelect, yearSelect, plotSelect], outputs=[plotVisual])
yearSelect.change(make_plot, inputs=[citySelect, yearSelect, plotSelect], outputs=[plotVisual])
plotSelect.change(make_plot, inputs=[citySelect, yearSelect, plotSelect], outputs=[plotVisual])
```

The dashboard is initialized with a default plot using the 'load' method:

```python
demo.load(make_plot, inputs=[citySelect, yearSelect, plotSelect], outputs=[plotVisual])
```

This implementation demonstrates the power of Gradio in creating interactive data visualization dashboards, combining the data manipulation capabilities of pandas with various plotting libraries to provide a rich user experience for exploring THI data [79] [80] [81].

[79] https://stackoverflow.com/questions/73413971/get-unique-years-from-a-date-column-in-pandas-dataframe

[80] https://pandas.pydata.org/docs/getting_started/intro_tutorials/09_timeseries.html

[81] https://www.perplexity.ai/page/dashboard-with-python-BdUUSg2BRzO29snUW5wAaw

Conclusions

The development of interactive data visualization dashboards using Python has significantly enhanced the ability to analyze and present complex datasets, particularly in fields like air quality analysis. Gradio emerges as a powerful tool in this domain, offering a user-friendly approach to creating web interfaces for machine learning models and data visualization without extensive web development expertise [82] [83].

Key advantages of using Gradio for dashboard creation include its Blocks API for flexible layouts, interactive components for dynamic user inputs, real-time updates, and seamless integration with popular data analysis libraries [83]. These features enable developers to create sophisticated, interactive dashboards that allow users to explore data intuitively, as demonstrated in the air quality analysis example [83] [84].

The process of sharing machine learning models through Gradio involves defining input/output interfaces, launching the interface, enabling user interaction, and performing computations on the host machine [84]. This streamlined workflow facilitates rapid prototyping and easy sharing of models with remote collaborators [84].

For creating visualizations, Gradio's Plot component supports multiple plotting libraries, including Matplotlib, Plotly, and Bokeh, offering flexibility in visualization techniques. The air quality dashboard example showcases the implementation of various plot types, such as calendar plots, box plots, and time series plots, demonstrating the versatility of Gradio in handling different visualization needs.

In conclusion, Gradio has established itself as a valuable tool for creating interactive data visualization dashboards, particularly in scientific and environmental applications like air quality analysis. Its ease of use, flexibility, and powerful features make it an excellent choice for researchers and developers looking to create engaging and informative data presentations.

[82] https://www.linkedin.com/advice/3/how-can-you-write-compelling-conclusion-scientific-rnref
[83] https://blog.wordvice.com/how-to-write-a-conclusion-for-a-research-paper/
[84] https://www.umgc.edu/current-students/learning-resources/writing-center/writing-resources/writing/essay-conclusions

Self-Assessment Task

Try out **Python code** by following the instructions and using the resources in the 6th Topic "Low-code framework for visuals with Python" (https://open.ktu.edu/course/view.php?id=191&section=8) of the MOOC "Big data"(https://open.ktu.edu/course/view.php?id=191).

TOPIC 3.7. Dashboard in R & Overview

After completing the topic learners will be able to create a dashboard with R flexdashboard library.

Overview of this topic

- Overview of R flexdashboard as a dashboard solution
- Different types of solutions available with R flexdashboard
- Examples showcasing static and interactive results
- Sample layouts for visual representation in dashboards
- Comparison of popular dashboard solutions in R and Python

Instructions for learning activities

1. Try R code in posit.cloud or RStudio;
2. For support use chatbot below or chat with the notes.

Topic content

Introduction

The flexdashboard package in R provides a robust framework for creating both static and Shiny-powered interactive dashboards using R Markdown, allowing users to effectively organize and present data visualizations through customizable layouts and components. It supports the integration of interactive elements and static content, making it a versatile tool for R users to develop dynamic and informative dashboards tailored to specific data visualization needs.

Lesson 3.7.1. Dynamic histogram with R and Shiny

To create a flexdashboard in RStudio, you can start by selecting "File > New File > R Markdown..." and then choosing "From Template > Flex Dashboard" [85] [86]. This will generate a basic template for your dashboard.

Flexdashboard offers two main types of solutions:

1. Static HTML dashboards: These are simple, non-interactive dashboards generated as HTML files. They are easy to create and share, as they don't require a server to run [87].
2. Shiny-powered dashboards: These incorporate Shiny functionality, allowing for much greater interactivity and dynamic content [88] [87].

The basic structure of a flexdashboard R Markdown file uses headers to define the layout:

- Level 1 headers (‘#’) begin a new page in the dashboard
- Level 2 headers (‘##’) start a new column
- Level 3 headers (‘###’) create a new box within a column [86].

You can customize the layout using attributes, such as ‘{.sidebar}’ to create a sidebar [86].

To add Shiny functionality to your dashboard, include ‘runtime: shiny’ in the YAML header of your R Markdown document [88]. This allows you to incorporate interactive elements like input widgets and reactive outputs.

For example, a simple Shiny-powered flexdashboard might look like this:

```text
---
title: "Shiny Flexdashboard"
output: flexdashboard::flex_dashboard
runtime: shiny
---
```

```text
```

[85] https://pkgs.rstudio.com/flexdashboard/

[86] https://rmarkdown.rstudio.com/lesson-12.html

[87] https://epirhandbook.com/new_pages/flexdashboard.html

[88] https://github.com/rstudio/rmarkdown-book/blob/main/05-dashboards.Rmd

```
library(flexdashboard)
library(shiny)
library(ggplot2)

# Sidebar with input
sidebar {
  sliderInput("bins", "Number of bins:", min = 1, max = 50, value = 30)
}

# Main panel with reactive plot
renderPlot({
  ggplot(faithful, aes(x = eruptions)) +
    geom_histogram(bins = input$bins)
})
```

This example creates a dashboard with a sidebar containing a slider input, and a main panel with a histogram that updates based on the slider value [88] [87].

Flexdashboard also supports various other features like value boxes, gauges, and storyboards for presenting sequences of visualizations [88] [89]. These components can be easily integrated to create rich, informative dashboards tailored to your specific data visualization needs.

[89] https://bookdown.org/yihui/rmarkdown/dashboards.html

Lesson 3.7.2. Static histogram with R flexdashboard

To convert the Shiny-powered flexdashboard into a static HTML variant, we need to remove the Shiny-specific elements and pre-compute the data for visualization. Here's how to modify the previous example:

```text
---
title: "Static Flexdashboard"
output: flexdashboard::flex_dashboard
---
```

```text
library(flexdashboard)
library(ggplot2)

# Pre-compute data for multiple bin sizes
plot_data <- lapply(c(10, 30, 50), function(bins) {
  ggplot(faithful, aes(x = eruptions)) +
    geom_histogram(bins = bins) +
    ggtitle(paste("Histogram with", bins, "bins"))
})
```

```text
# Display pre-computed plots
plot_data[[1]]
plot_data[[2]]
plot_data[[3]]
```

This static version pre-computes histograms with different bin sizes and displays them sequentially [90]. The 'runtime: shiny' line is removed from the YAML header, and the interactive elements are replaced with pre-generated plots [91]. This approach creates a lightweight, portable HTML file that can be easily shared and viewed without requiring a Shiny server [92]. However, it sacrifices the interactivity of the original Shiny-powered dashboard for improved portability and simpler hosting requirements [90] [92].

[90] https://www.fusioncharts.com/dev/exporting-charts/using-fusionexport/tutorials/export-a-dashboard

[91] https://www.reddit.com/r/homeassistant/comments/18hemli/export_dashboard_as_static_htmljs/?rdt=47543

[92] https://dev.to/themeselection/static-site-generator-1fp4

Lesson 3.7.3. Layout options for dashboard design

Flexdashboard offers a variety of layout options to organize and present data visualizations effectively. Here are some key sample layouts supported by flexdashboard:

- Chart Stack (Fill): This layout vertically stacks charts to fill the entire browser height. It's ideal for dashboards with 1-2 charts [93] .
- Chart Stack (Scrolling): For dashboards with 3 or more charts, this layout allows vertical scrolling. It uses 'vertical_layout: scroll' to maintain charts' natural height [93].
- Focal Chart (Top): This layout emphasizes a primary chart at the top, with secondary charts below. It uses 'orientation: rows' and 'data-height' attributes to control relative sizes [93].
- Tabset Row: This layout organizes content into tabs within a row. It's useful for presenting multiple related visualizations without cluttering the interface. Example syntax:

```text
Row {.tabset}

### Tab 1
### Tab 2 94
```

- Multiple Pages: For complex dashboards, this layout creates separate pages using level 1 markdown headers. Each page can have its own layout and orientation:

```text
Page 1
==================
### Chart 1

Page 2 {data-orientation=rows}
==================
### Chart 2 93
```

These layouts can be combined and customized to create tailored dashboards that effectively communicate data insights [95] [94] [93].

---

[93] https://pkgs.rstudio.com/flexdashboard/articles/layouts.html

[94] https://rstudio.github.io/flexdashboard/articles/using.html

[95] https://pkgs.rstudio.com/flexdashboard/articles/flexdashboard.html

Lesson 3.7.4. Full air quality dashboard code

Here's the full R Markdown code for the Temperature-Humidity Index dashboard for Kaunas:

```text
---
title: "Temperature-Humidity Index @ Kaunas"
output:
  flexdashboard::flex_dashboard:
   orientation: columns
   source_code: embed
   vertical_layout: fill
---

```{r setup, include=FALSE}
# Install / load required R libraries
if (!"pacman" %in% rownames(installed.packages())) install.packages("pacman")
pacman::p_load(dplyr, tidyr, ggplot2, plotly, dygraphs)
pacman::p_load(httr, data.table, dtplyr, xts, eurostat, pals, pbapply, doParallel)

euCodes %
  unite(urlLocations, c(urlLocation, "yNames", "qNames"), sep="")

# Download legacy data (in parallel)
csvFiles %
  rename(Value=all_of(mainCols)) %>%
  filter(Country %in% euCodes)

# Read legacy data files (in parallel)
parallel::clusterExport(cl, c("dropCols"))
parallel::clusterEvalQ(cl, pacman::p_load(data.table))
fileNamesQ %
  rename(Value=all_of(mainCols)) %>%
  filter(Country %in% euCodes)

# Append old (2018-2021) and new (2022-2023) data tables, sort, remove duplicates
dataTableEU % bind_rows(newTable) %>% arrange(Country, City, Date) %>%
  unique()

# Descriptive statistics for daily values of selected variables
selectedVars % filter(Specie %in% selectedVars)

# 2021-10-03 Barcelona fix
dataTableEU % group_by(Date, Country, City, Specie) %>% summarize(Value=mean(Value), .groups="drop")

# Create pivot table, calculate THI for each row, drop rows with missing THI values
selectedVars %
  pivot_wider(names_from=Specie, values_from=Value) %>%
  group_by(Date, Country) %>%
  mutate(across(all_of(selectedVars), ~ ifelse(is.na(.), median(.,na.rm=TRUE), .))) %>%
  mutate(THI = 0.8*temperature + (humidity/100)*(temperature-14.4) + 46.4) %>%
  filter(!is.na(THI)) %>%
  data.table

# Prepare data for selected city
myCity % filter(City==myCity, Date>='2019-01-01') %>%
  select(Date, humidity, temperature, THI) %>% mutate(across('THI', round, 2))
```
```

```
xts_data %
 dySeries(c("temperature"), label = 'Temperature') %>%
 dyCrosshair(direction = "vertical")
```

Humidity (%)

```text
# Plot humidity time series dynamics
dygraph(xts_data[,'humidity'], group = "Air-Data") %>%
 dySeries(c("humidity"), label = 'Humidity') %>%
 dyCrosshair(direction = "vertical")
```

Temperature-Humidity Index (THI)

```text
# Plot THI time series dynamics
dygraph(xts_data[,'THI'], group = "Air-Data") %>%
 dySeries("THI") %>%
 dyRangeSelector() %>% dyCrosshair(direction = "vertical")
```

About

Air Quality Open Data Platform and World Air Quality Index project team provides a new dedicated dataset, updated 3 times a day, and covering about 380 major cities in the world, from January 2015 until now. The data for each major city is based on the average (median) of several air quality monitoring stations. The data set provides min, max, median and standard deviation for each of the air pollutant species (PM10, PM2.5, NO2, Ozone, SO2, CO) as well as meteorological data (Temperature, Humidity, Wind). THI measures the level of discomfort the average person (or animal) is thought to experience as a result of the combined effects of the temperature and humidity of the air. The heat stress index THI is a simple combination of temperature and humidity (in decimal form) and can be calculated by the following formula (Habeeb, Gad and Atta, 2018):

$$THI = 0.8 \times Temperature + Humidity \times (Temperature - 14.4) + 46.4$$

Temperature-humidity indices as indicators to heat stress of climatic conditions with relation to production and reproduction of farm animals. International Journal of Biotechnology and Recent Advances, 1(1), 35-50. https://doi.org/10.18689/ijbr-1000107.

Descriptive statistics for THI

```text
knitr::kable(do.call(rbind, tapply(myTable$THI, year(myTable$Date), summary)), digits=2)
```

This R Markdown script creates a comprehensive flexdashboard for visualizing Temperature-Humidity Index (THI) data in Kaunas. It utilizes parallel processing for efficient data handling, incorporates interactive visualizations using ’plotly’ and ‘dygraphs’, and provides both static and dynamic calendar heatmaps. The dashboard offers a detailed view of temperature, humidity, and THI trends, allowing for in-depth analysis of climate comfort levels in Kaunas over time.

Lesson 3.7.5. Air quality dashboard explained

This R Markdown document creates a flexdashboard to visualize Temperature-Humidity Index (THI) data for Kaunas, Lithuania. The dashboard utilizes several advanced R packages and techniques for data processing, visualization, and interactivity. Here's a breakdown of the key components:

Component	Description
YAML Header	Specifies flexdashboard output with column orientation, embedded source code, and vertical fill layout
Setup	Loads required libraries using pacman, sets up parallel processing, and sources helper functions
Data Acquisition	Downloads recent and historical air quality data from the World Air Quality Index project
Data Preprocessing	Filters EU data, calculates THI, and prepares time series data for Kaunas
Visualizations	Creates static and dynamic calendar heatmaps, and time series plots for temperature, humidity, and THI
About Section	Provides context on the data source and THI calculation formula

The dashboard leverages several advanced R features:

1. Parallel processing for data download and manipulation using 'pbapply' and 'doParallel'.
2. Time series manipulation with 'xts' package.
3. Interactive visualizations using 'plotly' and 'dygraphs'.
4. Custom functions for URL downloading and heatmap creation.

The THI formula used is:

$$THI = 0.8 \times Temperature + Humidity \times (Temperature - 14.4) + 46.4$$

This dashboard provides a comprehensive view of temperature, humidity, and THI trends in Kaunas, allowing for both broad overview (via heatmaps) and detailed exploration (via interactive time series plots).

Lesson 3.7.6. Dashboard framework comparison

The following table provides a comprehensive comparison of popular dashboard frameworks in R and Python, highlighting their pros and cons:

Framework (Language)	Pros	Cons
Jupyter Notebook (Python, R)	* Versatile, supports both Python and R* Excellent for exploratory data analysis* Combines code, visualizations, and narrative	* Not specifically designed for dashboards* Limited interactivity without additional libraries
Flexdashboard (R)	* Easy to create using R Markdown* Supports static and Shiny-powered interactive dashboards* Flexible layouts with minimal coding	* Limited to R ecosystem* Less customizable than full-fledged frameworks
Jupyter-flex (Python)	* Brings flexdashboard-like functionality to Jupyter* Familiar for Jupyter users* Supports Voila for interactivity	* Less mature than other Python dashboard libraries* Limited customization options
Shiny (R, Python)	* Powerful and flexible for interactive web applications* Extensive widget library* Recently introduced Python version	* Steeper learning curve* Resource-intensive for complex applications
Dash (Python, R)	* Built on Flask, Plotly.js, and React.js* Highly customizable with React components* Supports both Python and R	* Complex setup compared to simpler frameworks* Requires web technology knowledge for advanced use
Panel (Python)	* Flexible for custom interactive web apps* Integrates well with Jupyter notebooks*	* Less mature than Dash or Shiny* Smaller community and

Framework (Language)	Pros	Cons
	Supports various plotting libraries	fewer resources
Streamlit (Python)	* Simple, intuitive syntax* Rapid prototyping and development* Ideal for data scientists with limited web dev experience	* Less flexible for complex layouts* Limited to Python ecosystem
Gradio (Python)	* Specializes in ML model interfaces* Simple API for quick prototyping* Easy to deploy and share	* Focused on ML model interfaces* Limited customization options
Solara (Python)	* Pure Python framework, no HTML/CSS/JS required* Reactive programming model* Good scientific Python ecosystem integration	* Relatively new, smaller community* May have limitations for highly custom designs
Taipy (Python)	* Combines data processing with GUI creation* Simple Python-based syntax* Suitable for end-to-end data applications	* Newer framework with fewer resources* Learning curve for its specific paradigm
Mesop (Python)	* Designed for large-scale data apps* Uses declarative approach similar to React* Good for complex, data-intensive applications	* Newer framework with smaller community* May be excessive for simpler dashboard needs
NiceGUI (Python)	* Simple, intuitive API for web UIs* Real-time updates and event handling* Suitable for simple and complex applications	* Less focused on data visualization* May require additional libraries for advanced data analysis

For R users, Shiny and Flexdashboard remain top choices due to their deep integration with the R ecosystem and powerful features. Python users have a wider range of options to choose from, depending on their specific needs:

1. For simplicity and rapid development: Streamlit or Gradio are excellent choices. They offer intuitive APIs and quick setup, making them ideal for data scientists who want to create dashboards quickly without extensive web development knowledge.
2. For flexibility and customization: Dash or Panel provide more advanced options. Dash offers high customizability with React components, while Panel integrates well with various plotting libraries and Jupyter notebooks.
3. For pure Python approaches: Solara or NiceGUI are emerging options. They allow developers to create dashboards using only Python, without the need for HTML, CSS, or JavaScript knowledge.
4. For complex data applications: Mesop or Taipy are designed for building large-scale, data-intensive applications. They offer more advanced features for handling complex data processing and visualization needs.

The choice of framework ultimately depends on factors such as the project's specific requirements, the team's expertise, development time constraints, and the desired level of customization and interactivity [96] [97] [98] .

[96] https://www.reddit.com/r/RStudio/comments/1cvnd4m/r_and_python_dashboard_recommendations/

[97] https://www.appsilon.com/post/dash-vs-shiny

[98] https://rstudio.github.io/flexdashboard/articles/shiny.html

Conclusions

Here are key conclusions about dashboard frameworks in R and Python:

- Framework diversity: There is a wide range of options available for creating dashboards in both R and Python, catering to different needs and skill levels.
- Language-specific strengths:
    - R excels with Shiny and flexdashboard for statistical analysis and data visualization
    - Python offers more general-purpose frameworks like Dash, Streamlit, and Panel
- Ease of use vs flexibility trade-off:
    - Simpler frameworks (e.g., Streamlit, flexdashboard) allow rapid development but may limit customization
    - More complex options (e.g., Shiny, Dash) offer greater flexibility but have steeper learning curves
- Emerging trends:
    - Increasing focus on pure Python solutions (Solara, NiceGUI)
    - Frameworks combining data processing and visualization (Taipy, Mesop)
    - Growing support for machine learning model deployment (Gradio)
- Cross-language compatibility: Some frameworks like Jupyter Notebooks and Shiny are bridging the gap between R and Python ecosystems.
    - Consideration factors: When choosing a framework, key factors include:
    - Primary programming language
    - Desired interactivity level
    - Development time constraints
    - Team skills
    - Deployment requirements
    - Long-term maintainability
    - Specific use case (e.g., data viz, ML deployment)

- No one-size-fits-all solution: The best choice depends on project requirements, team expertise, and specific use cases. It's important to evaluate options based on your unique needs [99] [100] [101] [102] [103].

[99] https://writingcenter.unc.edu/tips-and-tools/conclusions/
[100] https://library.sacredheart.edu/c.php?g=29803&p=185935
[101] https://www.cwauthors.com/article/how-to-write-the-conclusion-section-of-a-scientific-article
[102] https://www.perplexity.ai/page/dashboard-in-r-overview-2D8_gyYmSQ2ZSO7gFFMeHQ
[103] https://coachhallwrites.com/how-to-write-a-synthesis-essay-conclusion/

Self-Assessment Task

Try out **R code** by following the instructions and using the resources in the 7th Topic "Low-code framework for visuals with R" (https://open.ktu.edu/course/view.php?id=191&section=9) of the MOOC "Big data" (https://open.ktu.edu/course/view.php?id=191).

Practical Assignment

Select and solve your challenge for the *Casting of Urban Air Pollution* by following the instructions described in the section **Solving air pollution mini-challenge** (https://open.ktu.edu/course/view.php?id=191&section=2) of MOOC “Big data” (https://open.ktu.edu/course/view.php?id=191).

Sources

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4. ARTIFICIAL INTELLIGENCE

Relevance: The growing digitization of society is a reality that we have been witnessing, with the adoption of products and technologies that have transformed our personal lives, revolutionizing our relationship with information and communication. At the organization level, digital transformation is also motivated by the dissemination of several innovative technologies, potentially transforming business.

Objectives: This course addresses the main aspects of Artificial Intelligence (AI) and modern Machine Learning (ML) techniques, with a perspective of the impact on modern organizations, contextualizing them in business and organizational scenarios of digital transformation. The course will start by delimiting and defining the concepts of intelligence, AI and ML, followed by an overview of large areas within AI. Problem solving techniques are explored: for decision, search and optimization problems. Knowledge representation, as a key aspect, along with reasoning and uncertainty, is introduced, focusing on up-to-date methods. Besides the fundamental concepts of AI, studied since the 60s, recent developments in machine learning/deep learning and natural language processing (NLP) are introduced, by showing and experimenting with computational systems that are becoming increasingly available.

Learning outcomes: To develop and consolidate practical skills, challenge-based learning is proposed to the students, with some micro and medium size challenges, founded on real problems, and, if possible, in the context of industry or research partnerships. On successful completion of this course, graduates will be able to:

- Define what is artificial intelligence and main concepts and questions
- Analyze an intelligent agent, specifying its performance, analyzing environment characteristics and the characterize the different types of agents
- Understand and use of machine learning techniques, such decisions trees, neural networks and k nearest neighborhoods, with real data.
- Apply NLP models through available libraries

TOPIC 4.1. Overview of Artificial Intelligence

Learning Outcomes

By the end of this Topic on artificial intelligence, learners will be able to:

- Define what is artificial intelligence;
- Know the major areas of artificial intelligence;
- Understand what is done in each area.

Topic Content

Introduction

Lesson 4.1.1. Problem solving

Lesson 4.1.2. Knowledge representation and reasoning

Lesson 4.1.3. Uncertain Knowledge and Reasoning

Lesson 4.1.4. Machine Learning

Lesson 1.5. Communication, perception and action

Self-Assessment Task

Introduction

What is Artificial Intelligence?

- Building intelligent entities;
- Definition of intelligence
- Turing test

The goal of Artificial Intelligence is to build intelligent entities with the capacity to think and act intelligently. However, this goal uses the term intelligent without defining it. Much could be said about intelligence, but in order to have a definition that allows us to know if an entity is acting intelligently, we will use the rational approach.

The rational approach assumes that a being is intelligent if it acts rationally. In this case, the being is able to identify the correct action based on the knowledge it has. This definition is enough to know what kind of entities we are looking for when we talk about intelligent entities. But it doesn't provide any indicator of whether or not a being is intelligent, or what degree of intelligence it has.

The Turing test aims to answer this question by comparing it with the existing reference, the human being. The human being is the only usable model of intelligence.

The test consists of subjecting a human and a machine to questioning by a jury that doesn't know who is a human or a machine. If the jury can't distinguish between the two, the test is passed.

Even though the jury interface is textual, several areas of Artificial Intelligence are essential for the test to be passed, such as natural language processing, knowledge representation, reasoning and learning.

The test is focused on detecting intelligence. But can be extended to include the physical part. In this case, computer vision is important so that visible objects can be referred to. Robotics is also needed to be able to manipulate elements. The test can be restricted to assess just one area.

360º view of AI

Major areas of Artificial Intelligence:

- Problem Solving
- Knowledge Representation, Reasoning and Planning

- Uncertain Knowledge and Reasoning
- Learning
- Communication, Perception and Action

In this 360-degree view of Artificial Intelligence, we use the manual's division by parts, as well as the order of these parts. The first major area of Artificial Intelligence is problem solving. Given a problem with well-defined objectives, can the agent find a solution? The second main area is Knowledge Representation, Reasoning and Planning. How can knowledge be represented in a generic way, so that it can be used to reason and plan actions? The third area adds uncertainty to the second. How do you deal with uncertainty and make decisions with uncertain knowledge? The fourth area focuses on one of the main human capacities, the ability to learn. How can agents learn? Finally, the fifth area covers the agent's interaction with reality. Can the agent communicate through natural language, perceive the reality around it through sight and hearing, and carry out actions in that reality? [104]

[104] Artificial Intelligence: A Modern Approach, Stuart Russell, Peter Norvig, Prentice-Hall. https://aima.cs.berkeley.edu/

Lesson 4.1.1. Problem Solving

Problem Solving

- Decision Problems
- Search Problems
- Optimization Problems
- Adverse Search

How to use existing techniques

- Implement a technique in a programming language for the specific problem
- Define the problem in a generic solver

State of the art

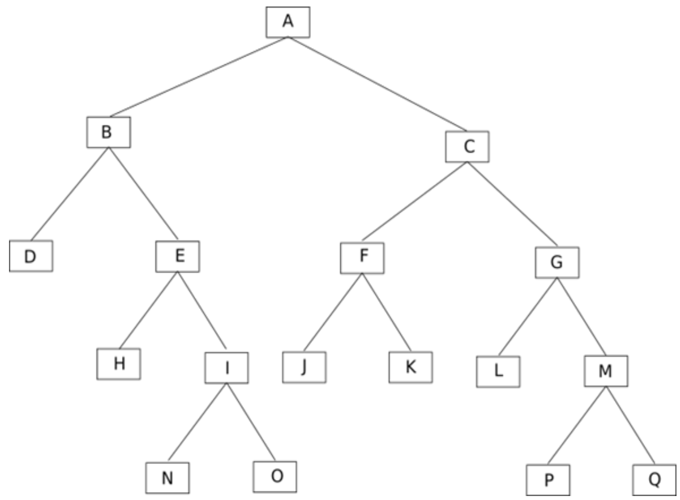
- Optimal solutions are found for specific problems
- Good solutions are found for other problems

Let's take a look at problem solving. Given a problem with well-defined objectives, can the agent find a solution?

This major area naturally intersects with other areas of science. In the context of Artificial Intelligence, we do need to be able to solve problems, otherwise it wouldn't be possible to have intelligent beings. However, in reality, well-defined problems are rare, most of them being simplifications of reality.

These problems can be divided firstly into the type of solution required. They can be decision problems, in which case you want to know a binary answer, yes or no. For example, given a network of trains and timetables, we want to know if there is a connection between two train stations A and B on a single day. These can be search problems if you want to find a solution, with all solutions having the same value. Re-using the previous example, we want to know a solution for getting from A to B, what sequence of trains to take. These can be optimization problems if you want to find the best-value solution among the solutions. In our example, we might be interested in the connection with the shortest time.

The main techniques available exploit the state space, as in the example on the right. State A will be the initial situation of the problem, in the case of the train example, being at station A at the start of the day. From state A there are two hypotheses, for state B or state C, which would correspond to catching a train at certain times. In each state there is a decision to be made, and the sequence of decisions made is the solution to be presented. Let's suppose that state N and state K both correspond to arriving at station B, therefore final states. In this case the decision problem would have a positive answer, the search problem could be A, B, E, I, N, or A, C, F, K. The optimization problem, in the case of identical station and journey times, the optimum solution would be A, C, F, K, as it is the shortest.



If there are other competitive agents, as is the case with games such as chess, the problem becomes one of adverse search. Many techniques are available, but they have to be implemented for each problem in computer languages. They naturally require in-depth knowledge of these techniques.

There are also generic solvers, such as the MS Excel solver. These solvers do not require knowledge of any technique to be used, but the results are inferior to dedicated implementations.

In this area, optimal solutions are achieved, i.e. a solution guaranteed to be the best, for small problems and for specific problems. In general, good solutions are achieved for medium and large problems, but there is no guarantee that it is the best solution.

The state of this area is already desirable for the ultimate goal of artificial intelligence. Of course, there could be a major revolution in this area. This would be the case if one of the oldest and most important problems in computer science were solved: whether or not P is equal to NP. The set P is the set of problems that are solved efficiently. In other words, the optimal solutions are obtained with algorithms limited polynomial by the size of the instance. The NP set is the set of problems that can be solved efficiently. But it is not yet known whether there are also algorithms for finding the solution efficiently in NP, which in that case would lead to P being equal to NP [106].

Lesson 4.1.2. Knowledge representation, reasoning and planning

- Propositional logic
- First-order logic
- Inference
- Planning
- Ontologies

The area of Knowledge Representation, Reasoning and Planning encompasses several aspects. Firstly, how do we represent knowledge in a generic way?

In the previous area, the knowledge of the specific problem is represented internally. If you change the problem, you have to build another representation. Only with a generic representation of knowledge can we acquire new knowledge and not have to program another agent. On the other hand, in the previous area everything is well defined, and in this area we want to represent what is known, which may not be completely defined.

Another point in this area is reasoning. How can we reason with the knowledge we have in order to build new knowledge? And finally, how can we plan a set of actions over time to achieve a given goal?

The main tool used to represent knowledge is logic. Through logic, we can represent facts that have occurred, as well as relationships between facts, so that we can infer new facts as soon as possible.

Firstly, we have propositional logic, in which there are no variables, and first-order logic, with variables and quantifiers.

Suppose you have the following knowledge base:

$$(P \wedge Q\ ) \Rightarrow (R \vee S), P, \neg R$$

Show, using the Modus Ponens and/or AND-elimination inference rule, that one can conclude:

$$\neg Q \vee S$$

There are more methods available for propositional logic. In the problem on the right, the knowledge base has the facts P, Q, S and R, and there are known relationships. We can conclude not what or S through inference, knowledge that didn't exist before.

1. $(P \wedge Q) \Rightarrow (R \vee S)$
2. P
3. $\neg R$
4. $\neg P \vee \neg Q \vee R \vee S$ (1)
5. $(\neg P \vee \neg\neg R) \vee \neg Q \vee S$(4)
6. $(P \wedge \neg R) \Rightarrow (\neg Q \vee S)$ (5)
7. $P \wedge \neg R$ (2,3)
8. $\neg Q \vee S$ (6,7)

The Modus Ponens and And-Elimination rules were used, which are sufficient rules of inference to conclude everything that can be concluded.

Other techniques exist, but the main limitation is that propositional logic can only represent facts, and there are no variables. Variables are essential to represent generic knowledge, i.e., applicable to any value of the variable.

Suppose you have the following knowledge base:
- Everyone likes to eat some type of food;
- There is no type of food that is enjoyed by all people;
- There are those who like all types of food;
- Fernando doesn't like cod.

Convert this information to 1st order logic

The exercise below asks you to convert knowledge in text into first-order logic. In this logic you can already represent variables, and therefore represent more generic knowledge, applicable to an arbitrary number of entities.

$$\forall_x \exists_y Person(x) \Rightarrow Food(y) \wedge Like(x,y)$$
$$\forall_x \exists_y Food(y) \Rightarrow Person(x) \wedge \neg Like(x,y)$$
$$\exists_x \forall_y Person(x) \wedge \left(Food(y) \Rightarrow Like(x,y)\right)$$
$$\neg Like(Fernando, Cod)$$

Existential and universal quantifiers can be used. This logic is more flexible and can represent universal knowledge.

Planning makes it possible to plan actions on a knowledge base in logic. Actions are defined that can be carried out if the preconditions are met. They have an effect by changing the knowledge base.

In the example, we have an action called "Flight", with 3 arguments. In the preconditions we see that the action can only be applied if p is an airplane, and the other two arguments are airports. In addition, p must be at the departure airport.

```
Action(Flight(p,from,to),
  precondition: In(p,from) and Airplane(p) and
        Airport(from) and Airport(to)
  effect: remove In(p,from), add In(p,to)
```

The effect if the action is placed in the sequence of actions is that the fact that Em(p,de) is removed from the knowledge base. In other words, the airplane p is no longer at the current airport. On the other hand, a fact is added, placing the airplane at the destination airport.

A problem is defined with an initial knowledge base, the possible actions are defined, as well as an objective. The agent looks for a solution consisting of a sequence of actions that will satisfy the objective. This model can be further improved by adding action durations as well as resources. It can deal with resource constraints and there are several precedence's between actions, but also actions that can be executed in parallel.

In methods, the knowledge relevant to the problem is provided, although there are generic techniques for dealing with knowledge. However, there is universal knowledge that the agent could hold, so it doesn't need to be provided for every problem.

To represent everything that exists, ontologies are constructed. A universal ontology would have the potential to define for a given problem only what is specific to the problem, and automatically the universal knowledge that is needed would be utilized.

The problem in this large area is the difficulty in obtaining universal ontology. In planning, it is the addition of too many actions that will increase the search space to unaffordable values. The representation of temporal, spatial and other knowledge is also a problem. A major limitation is the issue of uncertainty in knowledge, which is dealt with in the next major area [106].

Lesson 4.1.3. Uncertain Knowledge and Reasoning

- Uncertainty
- Representation of uncertain knowledge
- Inference
- Utility theory

Let's now focus on the area of Artificial Intelligence that deals with uncertainty. The main tool for dealing with uncertainty is of course probability theory. The degree of certainty that a given fact is real can be represented by a probability, the probability of being right.

All probability theory is useful, with a particular focus on Bayes' rule. This rule can be used to infer new knowledge.

In this area we also have utility theory. This takes a more simplified approach to supporting complex decisions. It allows beliefs, desires and uncertainty to be combined. This theory will advise the solution with the maximum expected utility.

To do this, it converts all the components of a possible solution into units of utility, such as cost. Naturally, the cost-utility curve can be different depending on the decision-maker. If it's cheap, the increase in cost won't penalize the solution too much. If the solution is already considered expensive by the decision-maker, any increase in cost will greatly penalize the solution.

The utility function can be used in a similar way for other decision criteria, such as quality, guarantee, product or service characteristics. The utility function has the advantage of placing all the criteria in the same units. This makes it possible to combine them, otherwise you'd be adding up garlic and breadcrumbs.

The advantage of this theory is its simplicity, but it is in the utility functions that the information that is relevant to the decision-maker is codified. This information can hardly be generalized or reused in another situation, except in other identical decisions that have to be made.

This large area has some positive results, such as expert systems for specific areas of knowledge. In terms of general use, it suffers from the same problems as the area of knowledge representation. The aggravating factor is that obtaining information on uncertainties may not be a simple task, even with the large volume of data that currently exists. To be statistically valid, a probability must be measured using a random sample.

The data recorded is often from a biased part of the population. For example, it could be the people who answer a survey, or the part of the population that interacts on social networks [106].

Lesson 4.1.4. Machine Learning

- Learning from examples

Methods:

- Decision trees
- K nearest neighbors
- Neural networks

We've reached the great area of learning. How can an agent learn?

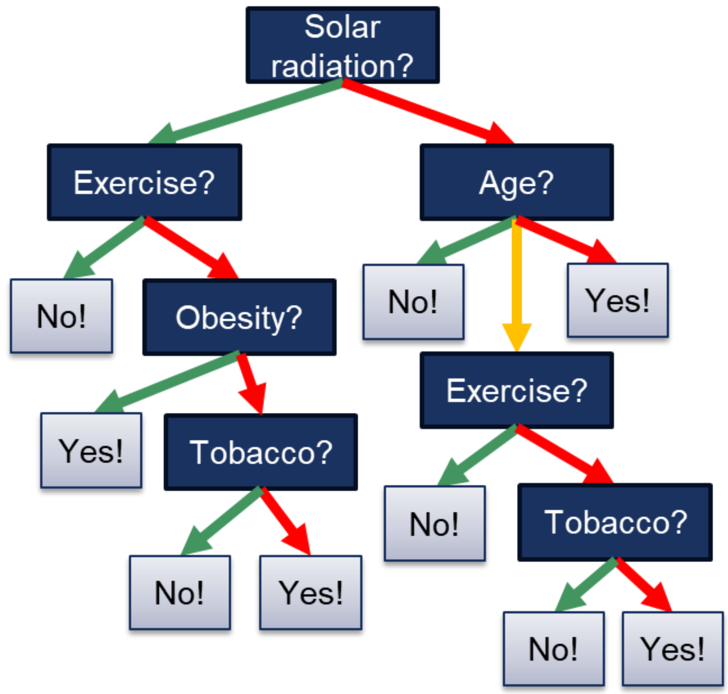
Learning is an essential characteristic of a truly intelligent agent. It can be built with lots of knowledge, but it certainly doesn't have the knowledge of the specific environment in which it will operate. On the other hand, there are changes that will need to be made over time, if it is to operate over a long period. Sometimes the knowledge doesn't actually exist, but there is data from which it can be extracted.

The main existing learning method is based on examples. This method is useful for learning the value of a variable, which will depend on other observed variables. In order to apply a learning method, there have to be many cases. If this value is high, and the sample relative to the population is not biased, the quality of the learning will be higher.

Decision trees are just one of the learning methods. These trees can be built automatically.

The same data can give rise to more than one decision tree. For the tree to be useful, it must be as small as possible and each node of the tree must be supported by a large number of examples.

This method has the simplicity of being open and therefore the entire network can be visualized. A user can understand the reason for a given classification.

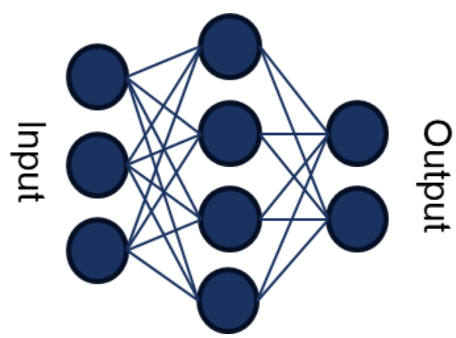


Another simple method is the K nearest neighbours technique. This method consists of defining a distance between examples. To classify a new case, it obtains the K closest examples according to this distance measure.

The most frequent classification in the K nearest examples is returned as the classification.

Visualizing the reason for a classification is not so clear, but the K examples used can be shown. Its simplicity makes it possible to add the visualized future examples to existing knowledge without having to redo a decision tree.

Many other methods exist, but one is unavoidable given its inspiration in the human brain itself. We're talking about neural networks.



A neural network, if it's big enough, can learn any kind of knowledge, including whether a chess position is good or bad. Neurons connect to each other, usually organized in layers.

The first layer has the inputs for each neuron and these are the dependent variables. In the last layer are the output variables, what we want to know.

Each neuron is very simple, it just does a weighted sum with the weights of the neurons it depends on. It then converts the result to a value between 0 and 1. The weights of each neuron need to be fine-tuned, and this requires a training set with many cases. Whenever there is an incorrect response in a training case, the weights that caused that response are adjusted up or down slightly. This way, the next time an identical case occurs, the response will be closer to the desired one.

This method has the disadvantage of being closed. In other words, when the user gets the answer, they don't have a justification that they can understand.

These methods are fully operational and can be used on a daily basis. In terms of Artificial Intelligence, this area has yet to discover methods that can learn unstructured knowledge.

In this case, the knowledge that the agent learns is previously indicated by the person using the method. A relationship is learnt between the dependent variable and the independent variables provided. Something different is that the agent can learn a new language, or a new subject, or create new knowledge by contributing to research [106].

Lesson 4.1.5. Communication, Perception and Action

- Natural Language Processing
- Communicating in Natural Language
- Perception
- Robotics

The last major area focuses on the agent's interface with reality.

This requires processing natural language and communicating in natural language. In terms of perception, the agent must be able to see and hear reality. In terms of actions, robotics is the area that will allow the agent to act in reality. Much of the information available is in text format. Natural language processing is crucial if the agent is to have existing information available to humans, which is therefore unstructured information. Text processing makes it possible not only to carry out searches, but also to categorize texts and extract structured information. Other uses include automatic summarization, which could become a useful tool for reducing the time it takes to read large texts. Translating texts between different languages is another use. There are also automatic questions and answers based on a large volume of text.

ChatGPT, launched in 2022, provides a very positive response along these lines.

In the exercises in the course, there is a proposal to reflect and then chat with ChatGPT on the subject.

Naturally, speech recognition, processing audio, is another highly developed area. The opposite is also important, the so-called synthesis voices. These allow the agent to verbalize a given written text. These functionalities are already available, in particular in the Edge browser we can request the reading of any page or PDF.

In perception, the agent needs to be able to visualize the world and create a 3D model of the reality around it. This requires image processing techniques, as well as identifying objects and their position. It is possible to quickly identify in an image whether or not there is a given object, and its location. Or even a person, including the position of the person's skeleton.

However, only one type of information can be obtained from each image. There is no generic solution for identifying all movable and immovable objects through a set of images.

The field of robotics has produced several robots with a variety of sensors and actuators, with a humanoid appearance like the one in the picture below left, or dedicated to a specific function.

This area already partially fulfills the goal of Artificial Intelligence, although it falls short of what some had hoped for. However, it has produced many tools that are used in everyday life [106].

VIDEO 4.1.1. Overview of Artificial Intelligence [*duration 23:03 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=13901

Self-Assessment Task

Test your knowledge by taking the test **Provocative question about Artificial Intelligence** (https://open.ktu.edu/mod/quiz/view.php?id=10643) in the 1st Topic "Overview of Artificial Intelligence" of the MOOC "Artificial Intelligence" (https://open.ktu.edu/course/view.php?id=190).

TOPIC 4.2. Intelligent Agent

Learning Outcomes

By the end of this lesson on artificial intelligence, learners will be able to:

- Analyze an intelligent agent;
- Identify performance indicators for an agent;
- Analyze environment characteristics of an agent;
- Characterize the different types of agents.

Topic Contents

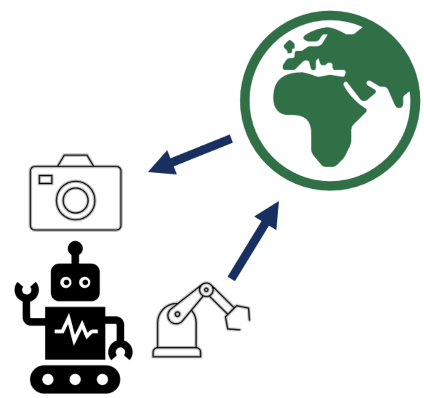
Lesson 4.2.1. Agent concept

- Definition of an agent
- Rational agent

An agent is something that can be seen as being in an environment. Captures the environment through sensors. It acts on the environment through actuators.

We can see in the figure, an abstract example of an agent. The robot is equipped with a camera, which allows it to capture images of reality. Reality is symbolized by the green world. On the other hand, the agent has an actuator, a mechanical arm. With this arm you can act on reality.

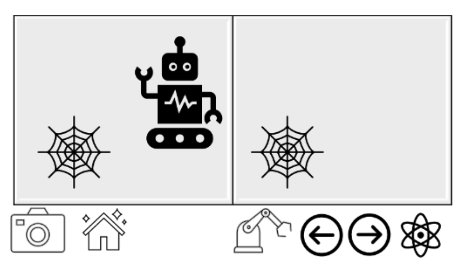
This is a generic concept. The environment may not be the world. Sensors may also vary, and may not include vision.



Actuators may also not be mechanical arms. The sensors and actuators are chosen according to the agent’s task. The agent's actions will depend on what he can observe. As a result it will perform actions.

The agent is rational if he does what is correct, based on the knowledge he has. We need to elaborate on what is correct, so let's introduce a simple example.

Our agent is responsible for cleaning two rooms. The rooms are together. You can move left or right.



You can also vacuum the current room, in which case the room will be clean. As a sensor, it can tell if the room is clean or dirty. You can also know which room you are in, whether it is on the left or right.

A possible behavior of the agent is the following:

- If the room is dirty, vacuum the room.
- If the room is clean and, on the left, go right.
- If the room is clean and, on the right, go left.

We can say that this agent is rational. Regardless of the initial condition, both rooms are clean in a short time. However, without realizing what is valued, we cannot support such a statement. This procedure may even have energy expenditure implications. After the rooms are cleaned, the agent will move between rooms.

To support that the agent is rational, we need:

- Performance indicator, which defines the success of the agent's task.
- Initial agent knowledge.
- Actions that the agent can perform.
- Sequence of observations carried out by the agent.

Only then are we in a position to evaluate the agent. We can also consider the methods that the agent can use, and their usefulness for the task in question.

It is therefore of capital importance to characterize the agent and everything that surrounds him [105].

[105] Artificial Intelligence: A Modern Approach, Stuart Russell, Peter Norvig, Prentice-Hall. https://aima.cs.berkeley.edu/ - Chapters related with this topic: Chapter 2 - Intelligent Agents

Lesson 4.2.2. Characterization of an agent

- Performance indicator
  - Quantifiable
  - Goals
  - Operational
- Environment
  - 1D; 2D; 3D. +1D.
- Actuators
- Sensors

We will characterize the agent, through its task, based on four factors.

The first is the performance or performance indicator. A performance indicator serves to quantify the agent’s performance. So, we can compare different performances for different implementations. We can also compare the agent's performance, according to different initial conditions. Naturally, the performance indicator must reflect the agent’s objectives. Sometimes the objectives are conflicting, so there has to be a compromise.

On the other hand, some objectives are restrictions, they cannot occur. In this case, these objectives should greatly penalize the indicator, if they occur. A performance indicator must be operational, that is, easily measurable. There is no point in having a perfect indicator if its calculation is impractical. It must also have a well-defined measurement period, and have units. It must be clear whether you want to maximize or minimize.

This is the only way to compare two or more agents. We can also support whether or not the agent is rational. To support that an agent was not rational, there must be some sequence of actions with better performance. We can indicate these actions and how they could have been deduced with the agent's knowledge.

We have some examples of agents. Suppose we have an agent who has to manage an elevator in a busy hotel. A good indicator is the minimization of a customer's maximum waiting time, measured throughout the day. Optimizing the average waiting time can lead to long waits on a less busy floor.

The second factor is the environment. As environment, we refer to the environment that the agent has to carry out its task. This environment can be removed from part of reality. It could be the area where the agent moves, as in the case of the cleaning agent, the two rooms. But it can also be virtual, as in the case of an agent that processes text and produces text. It will be a software agent. We have one of these agents, whose task could be arbitrarily complex. Its environment is the textual interface.

Let's characterize the environment by the number of dimensions it has to consider. In the case of elevators, we consider the 1D environment. This is because the elevator moves linearly. The same goes for the train. Although there may be forks, the environment is mostly linear.

A car can be considered to be in a 2D environment. Although it moves mostly by road, it has 2D movement options. The helicopter has 3D movement, although it may depend on the task. If the agent is fire surveillance, it may be another agent responsible for maneuvering the helicopter. In this case, the agent can only indicate the route in 2D. This route is converted by the navigator agent, who will deal with details of the helicopter maneuver.

The +1D component is added when time is a relevant factor.

The third factor is the actuators. With actuators, the agent modifies the environment. They have to allow the agent to do their job. They are not necessarily just actuators that allow the agent to move in the environment. A traffic light system controlling a complex node can be an important agent. In this case, the agent can change the period of the traffic lights, in order to flow more traffic. In the case of the software agent, the actuators can be files generated by the agent, or emails sent.

The fourth and final factor are the sensors. Sensors are the way it observes the environment. You should be able to observe what is relevant to your task. Sensors are not necessarily vision. These could be sensors to quantify the number of people waiting for the elevator. As soon as there is one person on a floor, the performance indicator may worsen if that person is not attended to. The sensor can be audio, or the entire internet, such as GPS position.

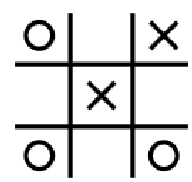
When designing an agent, these four factors must be described as best as possible [107].

Lesson 4.2.3. Properties of an environment

- Completely / Partially observable
- Deterministic / Stochastic
- Episodic / Sequential
- Static / Dynamic
- Discrete / Continuous
- Uni-agent / Multi-agent

The environment and tasks that the agent has to perform are very diverse. We can, however, characterize some properties.

Firstly, the agent may or may not completely observe the environment. In case the agent captures the entire environment, it will be completely observable. Otherwise, it will be partially observable. A case of a completely observable environment, it is a deterministic game. We have a game of chicken here. When making a bid, the agent observes everything that exists and is relevant to his action.



An agent who moves on a competition motorbike may have the objective of traveling on tracks. He can't observe the entire track. Partially observes the track and the position of opponents in your field of vision.

The environment can be deterministic or random. The environment is deterministic if the next state is determined by the current state and the agent's action. If there are other factors that do not allow the agent to predict the next state, then the environment is random. As a deterministic example, we have the software agent. After obtaining the input data, the output depends only on the program.

As for the agent sailing a sailing boat, it depends on random factors. The wind may vary, and a given sail position may not have the expected effect. On the other hand, the waves and currents of the sea can drag the boat. In this way, the boat can move due to actions beyond the control of the agent.

The environment can have the property of being episodic or sequential. In an episodic environment, the agent acts in a scenario, separate from the next scenario, so they are not related. This is the case with the processing of audio files. Suppose the agent has to extract lines from previously recorded files. Each file is distinct from the previous one, so the environment is episodic.

In the sequential environment, the sequence of actions is relevant. It will be most situations. For example, the tractor, assuming that it is an agent who intends to plow agricultural land. His actions must have a sequence. It is important to have the area already plowed so you can go work in another area.

Another characteristic of the environment is whether it is static or dynamic. If the environment can change while the agent thinks, then the environment is dynamic. Otherwise, it is static. An example of a static environment is the agent that controls elevators. People arrive at any time. However, the agent's thinking time is much shorter. You can think whatever you want, but in terms of waiting time it is insignificant. The mechanical movement of the elevator is the limiting factor.

The helicopter is dynamic, if we consider the agent that controls the movement.

We also have a property of the environment; it can be discrete or continuous. The environment is continuous if the state requires continuous data, otherwise it is discrete. We can use the game agent again, to exemplify a discrete agent.

The state in which the agent can be can be described by discrete variables. The agent who controls a motorcycle must have a lot of continuous information. The position of the bike, but also the vertical orientation, for balance.

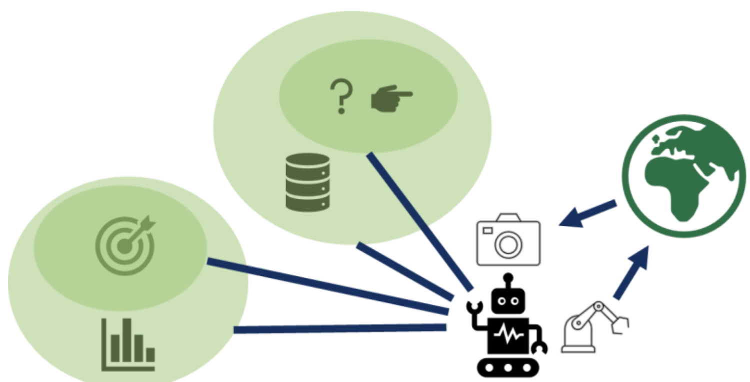
Finally, we arrived at the last property. The environment can be uni-agent or multi-agent. The environment is uni-agent if there is only one agent in the environment. If there are other entities, they must be indifferent to the agent's objectives. The environment is multi-agent if there are other entities. These entities must be collaborators or adversaries of the agent. They may even be neither one thing nor the other, but simply have conflicting objectives [107].

Lesson 4.2.4. Types of agents

- Simple reflex agent
- Model reflex agent
- Objective agent
- Utility Agent

We can classify agents at the implementation level.

We have the simplest agent of all. The simple reflex agent. This agent has a set of rules. Whenever a rule applies, there is an action that the agent must take. The agent has to use the sensors, and see which rule applies. Finding a rule, apply the rule.



This type of agent is easy to implement, having no memory. However, all rules must be specified. These must be taken carefully, seeing all possible implications. It just depends on current perception.

A more advanced version of this agent is the reflex agent with a data model. This agent can store everything captured by the sensors. Information now may be useful moments later. You can also save other information with the status it is in. Thus, this agent can take actions that depend on its entire operating period. It will still have a set of rules, and therefore a reflex agent. For each situation, actions are defined. Identifying the situation can be more complex. It may involve internal data about the agent's state, such as everything the sensor has observed in the past.

We can also have an agent per objective. We define the objective, and with a search method, we look for a solution. Once the solution is found, the solution is executed.

The solution was not explicitly given by a set of rules. Only the objective was given, having to resort to algorithms that try to identify the best solution.

There are, however, situations in which there are several objectives. The objectives are sometimes conflicting. A commitment has to be made. In these situations, we can define a utility function. The utility function will indicate the value of each solution to the agent.

It is linked to the performance indicator, but it is an internal value. Thus, the agent can look for not just a solution, but the best solution. There is greater flexibility to model what you want. The problem that was one of demand, becomes one of optimization. But the methods exist just the same. This way, generic methods can be used, only needing to define the utility function [107].

VIDEO 4.2.1. Intelligent Agents [*duration 15:31 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=13900

Self-Assessment Task

Test your knowledge by taking the test **Intelligent Agent Characterization** (https://open.ktu.edu/mod/quiz/view.php?id=10682) in the 2nd Topic “Intelligent Agents” of the MOOC “Artificial Intelligence” (https://open.ktu.edu/course/view.php?id=190).

TOPIC 4.3. Introduction to Machine Learning: Learning from Examples

Learning Outcomes

By the end of this lesson on artificial intelligence, learners will be able to:

- Understand machine learning techniques;
- Use decision trees, neural networks and k nearest neighborhoods, with real data.

Topic Content

Introduction

Lesson 4.3.1. Decision trees

Lesson 4.3.2. Assessment

Lesson 4.3.3. Linear regression

Lesson 4.3.4. K nearest neighbors

Lesson 4.3.5. Combine learning

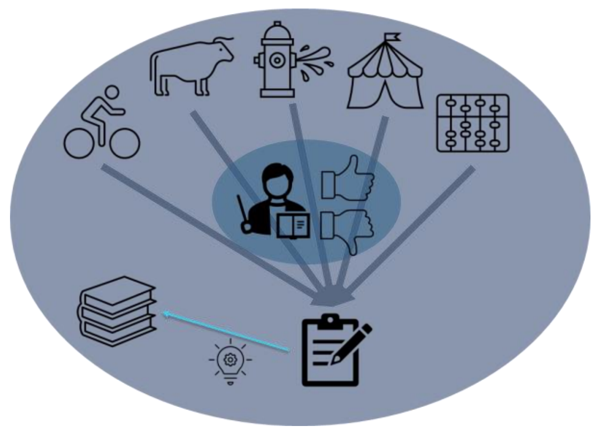
Lesson 4.3.6. Neural networks

Practical Assignments

Introduction

- Learning
- Induction/deduction
- Classification/Regression

An agent learns if it can improve its performance through past cases. A case may correspond to the actions and observations that the agent performs, or just observations. For simplicity, we will use the term observation more, although in this case there may be agent actions.



The figure has a set of observations made by the agent. There is feedback regarding each of the observations. This feedback is a guide to improving the agent's performance. Based on this set of pairs of observations and feedback, the agent must obtain knowledge. With this knowledge, your performance improves.

We call induction the ability to construct rules from examples. Deduction allows you to build knowledge based on existing knowledge. Knowledge constructed by induction can be wrong. It depends on the examples, which may not be representative of all reality. Knowledge constructed by deduction is correct if prior knowledge is correct.

The nature of what can be learned can be very diverse. Any component of an agent can be subject to learning.

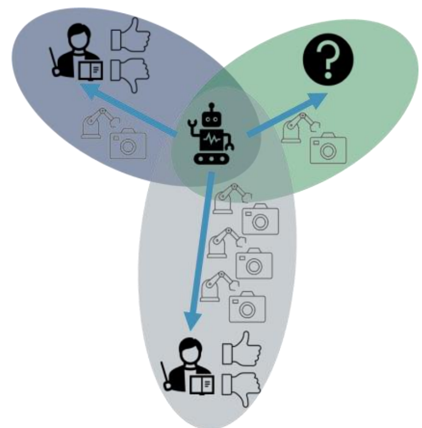
We separate learning methods based on the nature of what you want to learn. If we want to know an answer to a true or false question, or with discrete alternatives, then we have a classification. An example of a classification is knowing whether a student will pass a curricular unit. In this case we have a binary variable, it is a Boolean classification problem.

But we might want to know a person's club, which has as its answer a discrete finite set of possibilities. If we want to know the answer to a continuous variable, then we have a regression. An example of a regression is trying to find out tomorrow's maximum temperature.

The observable variables used for classification or regression can be of any nature, continuous or discrete. This subject intersects with statistics, so some of the methods are common. The names of independent variables are normally used for observations, and dependent variable for what we want to know.

Types of learning

- Supervisioned
- Unsupervised
- Reinforced



There are three types of learning. The first is supervised learning. It is this type of learning that we will focus on in this lesson.

In this learning, the agent observes reality and receives feedback for each observation. With this feedback you can learn from all the information. Learning is dependent on the existence of feedback, which does not always exist. Feedback may not always be correct. This is the blue branch in the image.

In unsupervised learning, there is no feedback. The agent must seek to extract information from the volume of data it receives. Typical methods will be clustering, identifying cases that are identical to each other. This is the green branch in the image.

In reinforced learning, the agent performs several actions. Receives feedback, yes, positive or negative, but for the set of actions. You don't know which actions are most responsible for the final result. For example, when playing a match, you will know at the end if you won, drew or lost. You are not given any indication of good and bad moves. This is the yellow branch in the image.

We can see these three types of learning in the context of distance learning. Supervised learning will correspond to a teaching model in which there is a forum. With the forum the student can ask questions about each observation and receive a response to each one. Reinforced learning will correspond to a teaching model, without a forum, but with assessment activities, or synchronous sessions. With the assessment activity or in the synchronous session, the student will receive the result related to the study actions they took.

Unsupervised learning will correspond to a teaching model, without a forum, without assessment activities and without synchronous sessions. In this case, it is the student's responsibility to seek to extract knowledge from the data they observe.

Supervised Learning

In supervised learning we have a set of observations and feedback. Let's call the observed data the training set. This set has pairs of variables X, with the observable variables of each case. The variable Y has the feedback, what we want to know. There is actually a function that converts variables X into variable Y. However, we do not know what this function is, we intend to learn. Thus, we have to assume that this function belongs to a given set of functions H. This is the set of our hypotheses. For each function in this set, we can calculate the value of X, and get a value for Y [106].

- Training set: $\{(x_1, y_1), \ldots, (x_n, y_n)\}$
- Real function: $y = f(x)$
- Hypothesis: $h(x) = \hat{y}, h \in \mathbb{H}$
- Example
  - Reality:
    - Students in a course
  - Observable variables:
    - Reading of materials;
    - Carrying out training activities;
    - Interventions in the forum;
    - Carrying out assessment activities.
  - Learn:
    - passing or failing the course

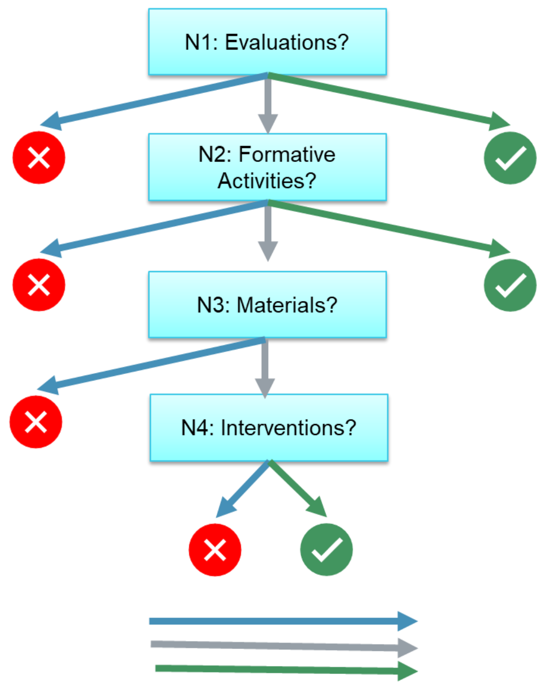
[106] Artificial Intelligence: A Modern Approach, Stuart Russell, Peter Norvig, Prentice-Hall. https://aima.cs.berkeley.edu/ - Chapters related with this topic: Chapter 18 - Learning from Examples

Lesson 4.3.1. Decision Trees

- Definition
- Expressiveness

Decision trees are the first learning method we present. A decision tree consists of having an observable variable at each node of the tree. For each value that the variable can have, we will create a branch. In leaf nodes, we place the result of the question we want to answer.

Let's see a decision tree. We see that in node 1 it asks for evaluation. Did the student take assessments? The arrows are in 3 colors, as there are 3 possible answers. Orange is for not accomplished, yellow for partially accomplished, and green for completely accomplished.



If you haven't carried out assessments, then you will fail. Thus the left branch ends with a negative answer. If you have carried out complete assessments, then you will approve. Thus, the branch on the right ends with a positive answer. If it was partially done, then we enter node 2.

This node asks about training activities. The situation is identical to node 1. If they were partially carried out, we enter node 3, materials.

This node has only two branches, as the observed data did not have any situation for the third branch.

Finally, we have node 4 also with only two branches, due to there being no observations for the other branch.

With each observation we can go through the questions in the tree, and end up at a final node with the value of what we want to know. This method allows learning and making knowledge visible, in a format of rules.

			N1: Evaluations?			
1			2			3
Grade 1			N2: Formative Activities?			Grade 2
	1		2		3	
	Grade 1		N3: Materials?		Grade 2	
		1	2			
		Grade 1	N4: Interventions?			
			1	3		
			Grade 1	Grade 2		

The same tree, in a spreadsheet, can be placed compactly. This format occupies as many columns as there are leaf nodes. The lines depend on the maximum depth of the tree.

We note that in a decision tree, we can place knowledge in propositional logic. The disjunctive normal form is ideal for constructing the tree. This format is a disjunction of conjunctions. Each conjunction will correspond to a branch of the tree. Any expression can be converted to disjunctive normal form. Thus, all knowledge in propositional logic can be represented in decision trees.

Build from cases

- Choose the most relevant attribute
- Split cases by attribute value

Having the decision tree is good, but if we have to build it manually, it can be a problem. The computer could not learn automatically. On the other hand, if there are many observations or there are many observable variables, building the tree may not be simple. We need a way to build it automatically. Let's give the algorithm for this purpose.

The algorithm has two main steps, and is recursive. First, there must be a way to choose which attribute is most relevant. An attribute is a characteristic, that is, an observable variable, of the specific case. Once the attribute has been chosen, the observations must be divided by the value of the attribute, and the algorithm executed recursively. Let's ignore the issue of the most relevant attribute for now.

Case	Materials	Formative Activities	Interventions	Evaluations	Grade
1	1	2	2	1	1
5	2	2	2	1	1
11	1	2	2	1	1
13	2	2	1	1	1
15	1	1	3	1	1
3	2	2	1	2	1
7	1	2	3	2	1
9	2	1	1	2	1
6	2	3	1	2	2
8	2	2	3	2	2
16	3	3	3	2	2
2	3	2	1	3	2
4	2	2	1	3	2
10	3	2	3	3	2
12	3	1	2	3	2
14	2	2	2	3	2

In the first step we considered that this attribute would be evaluations. Thus, we sorted the data by the value of evaluations. When the ratings are 1 or 3, the grade value is always the same, 1 and 2. So, let's put these values in the tree. The corresponding observations are no longer used.

For the case where the value fluctuates, we will extract the observations and repeat the process.

We can now see the training activities attribute to be chosen, having the values 1 and 3 with a single answer. Let's put this answer in the tree under construction, and extract the cases for answer 2.

Case	Materials	Formative Activities	Interventions	Grade
9	2	1	1	1
3	2	2	1	1
7	1	2	3	1
8	2	2	3	2
6	2	3	1	2
16	3	3	3	2

There are only 3 cases, but even so we don't have any attribute that solves it completely. We chose the material attribute, closing the case with an answer of 1. The other case is left for the end, with the missing attribute being chosen, the interventions. The entire table is done.

Case	Materials	Interventions	Grade
7	1	3	1
3	2	1	1
8	2	3	2

We can make decision trees like this, without worrying about the most important attribute.

We can simply choose what pleases us most at any given moment. The computer could choose at random. However, this way we can choose an irrelevant attribute. We do not know if all the observed attributes are relevant. In this case, we chose the attribute and nothing was gained. As a result, the tree remains valid, but has an unnecessarily large size.

Choosing the most relevant attribute

- Most solved cases
- Entropy
- Information gain

The choice of the most relevant attribute is linked to the concept of entropy. Before moving on to this concept, we can use a simpler rule. As in the previous tree it was nice to have reduced several cases from the beginning, we can value this situation. We see which attribute allows us to solve more cases.As resolved cases, this means that they are associated with leaf nodes and are no longer processed.

Although this rule is simple, it is too simplistic for real cases. When there are many observations and attributes, it is unlikely that we will have any attribute at the first level that solves any case. In this case, the attributes would be equal, since none of them solved any case.

We need to increase accuracy on solved cases. This is where the concept of entropy comes in. Instead of solving cases, we reduce entropy. Entropy is a measure of information.

If we know nothing about the result of a Boolean variable, we have a 50 % chance of having one result or another. In this case we have entropy 1. However, if we have some kind of information, that information can change the probability. Entropy must therefore be reduced. In the extreme case of knowing the value of the variable, the entropy will be 0.

After the tree is built, we can prune the tree by doing statistical tests. If there is no statistical evidence, we remove the node and aggregate the upper node information. This operation is important in real networks, but for simplicity we will not give it here.

We can also have continuous variables. Or integer variables, but with many values. In this case we will not want to create a branch for each possible value. An example in this case would be the variable hours of study.

For these cases, we choose a cutoff point. We divide the cases that are superior, from the cases that are inferior. The different values for the cutoff point are candidates as if they were distinct attributes. We chose the cutoff point with the greatest gain in entropy. Manually resolving a variable of this type would imply having a column in the tables for each cutoff point [108].

Lesson 4.3.2. Assessment

- We consider that cases:
  - They have equal probability
  - They are independent
- Error: P($h(x) \neq y$)
- Sets:
  - Train
  - Validation
  - Test
- Model parameters
- Cross-validation

Let's now see how we evaluate our system. So we can choose the best function H. We also want to know the level of learning obtained.

To achieve this we must first consider that:

- All observations made have an equal probability of occurring.
- There are no more important than others.
- We also have to consider that they are all independent.

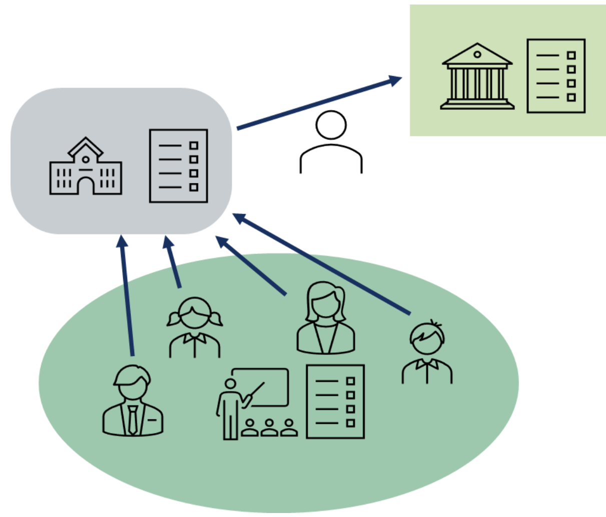
With these considerations, we can then calculate a first approximation for the error rate. We want to know the probability of making a mistake. In other words, knowing how often our function H will give a value different from what we want. For this purpose, we will need not only the training set, already mentioned above. We also need a validation set and a test set.

In case we only have one set of data, we can divide the data into these three sets.

The training set, let's say the cases given in the classroom. We see the teacher with several students, in this case simulating potential H functions. The teacher trains the students as best he can, using the training set heavily.

Now if you were to evaluate their performance based on the training set, you wouldn't be able to know if they had actually learned anything.

It is then a good idea to have another set, to validate what was learned in the classroom.



Thus, in a test carried out at school, with completely different observations, we will put the students' knowledge to the test. This knowledge will give an error percentage.

Let's choose the best one to represent the school. But its value must now be tested in another set, which has not yet been seen. If this were not the case, the school with many students could win just by luck. Even if all students know the same, one of them would be lucky and be classified as high as they deserve. Another school with just one student, but very trained, could be below this. Subjecting the best to a single final test solves this problem, determining real performance.

Students here are equated with hypothetical roles. Models may also have parameters that we want to test. In the decision tree, we can limit the maximum depth. Or put a limit on the number of observations each node must have to support it. For each different value of a parameter, we have a different function H under test. Thus, the validation set can be used to optimize existing parameters.

If the data volume is reduced, we can also use cross-validation. With the data from the test and validation set, we can exchange observations between these two sets. So, with the same data, we can retrain and validate again. The average value can be used as a validation result, and thus we have a better guarantee that we chose the best H function [108].

VIDEO 4.3.1. Introduction to Machine Learning - Learning from Examples - Part A [*duration 20:12 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=13895

Lesson 4.3.3. Linear regression

- Loss
- Univariate linear regression

In a regression problem, the variable we want to learn is continuous. Therefore, it no longer makes sense to know whether you were right or wrong. We have to quantify the error, since it is different to make mistakes by a little or by a lot. This function takes as an argument the real value and the estimated value, returning the loss. The loss is a value dependent on the agent's objectives.

We present three common loss functions.

The first is version 0 or 1, which considers a total loss if the values are different, otherwise there is no loss. This is the version we have used so far.

Loss $L(y, \hat{y})$

- 0/1: $L_{0/1}(y, \hat{y}) = 0 \; se \; y = \hat{y}, 1 \; c.c.$
- Absoluta: $L_1(y, \hat{y}) = |y - \hat{y}|$
- Quadrática: $L_2(y, \hat{y}) = (y - \hat{y})^2$

The second is absolute loss, which uses absolute value. This type of loss is interesting if each unit of difference has equal importance. It is also suitable when using variables of different natures. Although the scale of the variables can change the value of the loss, the variables can be normalized.

The third loss is the quadratic loss. This function gives more value to large differences, and does not give much importance to small differences. If the various variables are in the same units, this is the loss that will make the most sense. If there is no problem with small differences, but large differences, even if rare, are a big problem, then this loss may be the most advisable.

We can now consider a first situation of H functions. Let's consider all linear functions. These functions can be described based on two weights, W1 and W0.

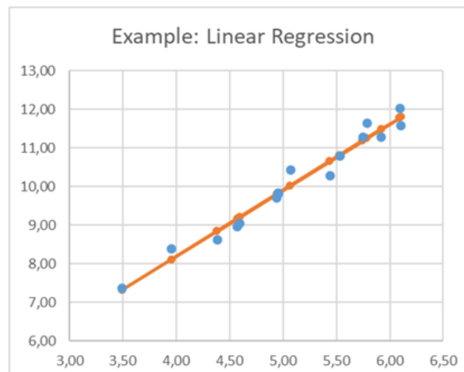
We want to know which linear function best approximates the data, with a single observed variable. It remains to say which loss function is used. We use quadratic loss. Thus, we can take the derivative of the loss, and obtain the exact values of the W constants.

The formula appears to be more complex than it actually is. Let's see a concrete example, generated by the real function. This function also has noise generated by a uniform distribution between 0 and 1. However, the sample is only 16 observations, so it is not expected to be able to obtain weights equal to those of the real function.

Univariate linear regression

- $h_w(x) = w_1 x + w_0$
- $w_1 = \frac{N(\sum x_j y_j) - (\sum x_j)(\sum y_j)}{N(\sum x_j^2) - (\sum x_j)^2}$
- $w_0 = \left(\sum y_j - w_1\left(\sum x_j\right)\right)/N$

We can see in the diagram that the resulting straight line approximates the generated points quite well. The value of the function h(x) can be calculated based on the best values of W.



So far so good, but if we now want to minimize the absolute loss, we have to do the math to find the exact values of W1 and W0. On the other hand, if we need more variables, we have to do more math again.

A generic method is therefore necessary to obtain the values of W1 and W0, for cases in which we do not have the algebraic expression.

Gradient Descent

The gradient descent method allows you to obtain the weights for normal loss functions, even without knowing the formula. The advantage is that it is a generic method that can be used in any context. This algorithm is like hill climbing, but for continuous values. It has its distinct name due to it descending rather than ascending. In this context we want to minimize losses.

- Initialize w_0, w_1
- Until it converges
  - $w_0 \leftarrow w_0 + \alpha \sum \left(y_j - h_w(x_j)\right)$
  - $w_1 \leftarrow w_1 + \alpha \sum \left(y_j - h_w(x_j)\right) \times x_j$

Just like mountain climbing, in this case we have mostly continuous variables, and we want to analyze the neighborhood. Among the neighbors, we intend to follow the one with the lowest cost.

The neighborhood here is analyzed through the difference between expected and obtained values. If the difference is positive, a higher value was expected and a lower value was obtained. So the weights must go up.

However, the weight is multiplied by the input data. Input data can be small or large. If they are large, then the weight is more responsible for the high result. If they are negative, then the opposite occurs, this weight contributed in a negative way. For this reason, the change in weight is multiplied by the input data.

In order to control the update step, we have to use an alpha value. This alpha value will ensure that jumps are not too long, which could complicate convergence.

Note that in this version for linear regression, we iterate over the entire training set, and only then update the weights.

Let's see next, for linear classification, the possibility of updating the weights in each observation.

Linear Classification

Linear classification is another possibility. With continuous variables, we intend to have a classification, in this case Boolean. We want to know whether the locations of accidents in a city involve pedestrians or just vehicles.

Cutoff

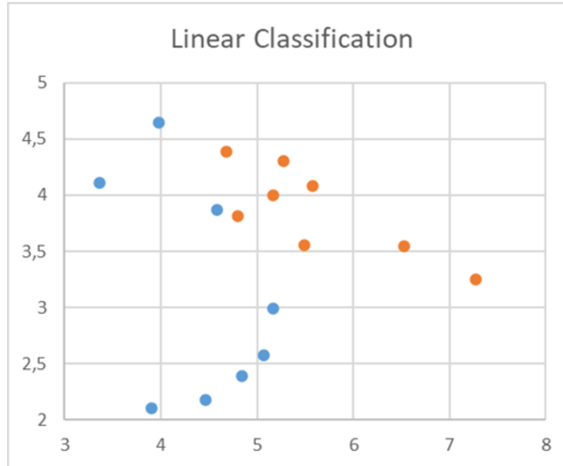
- $h_w(x) = 1 \; se \; w_2 x_2 + w_1 x_1 + w_0 \geq 0, \;\; 0 \; c.c.$
- $w_i \leftarrow w_i + \alpha\big(y - h_w(x)\big)x_i$

Logistics function

- $h_w(x) = \frac{1}{1+e^{-(w_2 x_2 + w_1 x_1 + w_0)}}$
- $w_i \leftarrow w_i + \alpha\big(y - h_w(x)\big)h_w(x)\big(1 - h_w(x)\big)x_i$

The variable Y will be 1 if it involves pedestrians, 0 otherwise. The information can be seen graphically in the scatter plot.

We intend for there to be a classification, assuming the space of linear functions. However, these functions return a real number. We can convert it to a Boolean value, through an activation function.



We can use a cutoff point. In this case we can choose a value from which the output is 1. We choose the value 0. If it is positive or null then the rating is 1, otherwise the rating is 0.

With this function we can have the identical update for the gradient descent as we used in linear regression. Instead of adding all the cases in the training set, we use just one case.

Note that we have two dimensions, for the same case, the value of W in one dimension can increase, with X in that dimension being positive. But if it is negative in the other dimension, the value of W in that dimension decreases, in the same case.

Thus, each weight is changed depending on the situation. In the case of W0, the value of X does not exist, but this weight is essential, so that there can be a value other than 0, when the data is null.

The cutoff point, however, is very drastic. The points may even overlap, and it may be interesting to have a measure of certainty, instead of 0 or 1.

A continuous function, which goes from 0 to minus infinity, to 1 at infinity, is the logistic function. We can use this function to convert the result of the linear expression into a value between 0 and 1. The logistic function has this simple look, 1 divided by 1 plus is raised to minus the argument. This function has the advantage that it can be derived, and it is simple to obtain a function to update the weight values. The expression is almost the same as the previous one, with a product [108].

Lesson 4.3.4. K nearest neighbors

- Non-parametric models
  - Use past cases
  - Use the K closest examples
- Nonparametric regression
  - K nearest neighbors
  - Locally weighted regression
- Support Vector Machines

K nearest neighbors is another distinct approach. It is the base approach for non-parametric models. A non-parametric model cannot be characterized with a fixed number of parameters.

In linear regression, in the first example we had two constants, in the second we had 3 constants. These constants are independent of the size of the training set. They are therefore parametric models, since the parameters, the weights, are fixed.

Likewise, decision trees have a fixed number of nodes. Each node in the tree, and orientation to other nodes dependent on the attribute value, can be considered parameters. These parameters are fixed, although the tree may be large in size.

Not in this case. We use the past cases directly. When a new case is received, we try to find the most similar cases, and return the aggregated value of these cases. Typically, the most common value.

Using the example of the class and the students, this would be the case of the student who does not study. When a test comes, at that point you will look for question-answer pairs that are closest, and adapt.

This method has the advantage, not only of not needing to be trained, but also of being able to be updated with new cases. As they are observed, they can be inserted, without the need for another type of update. It is considered simple, as only a distance measure between observations needs to be defined.

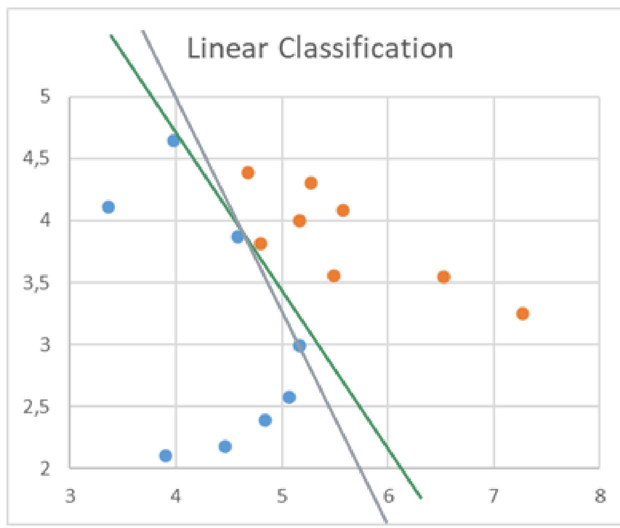
However, it can be tedious to find the K nearest neighbors if there are many observations and attributes. One possibility is to use a tree structure to divide cases according to the value of an attribute. They can be divided into several categories, and thus we can exclude categories that stay too far.

We can also have non-parametric regression, not just classification. In this case we have the K nearest neighbors again, and the value of the function can be an aggregation function, normally the average of these. This solution would have discontinuities, when passing from a point where the nearest neighbors change.

In order to make the regression continuous, we cannot average the neighbors, but rather the average weighted by distance. This means that the closest neighbors have greater value, losing value to 0, as soon as we move further away.

Another classification possibility is support vector machines. Linear classification seeks to divide the space into two, one for each category, with all divisions being good as long as they divide the points. In the figure there is a yellow division, which almost intersects two points, but actually separates the orange points from the blue points.

The green division is as far away as possible from the existing points. For linear classification purposes, both lines have zero error.

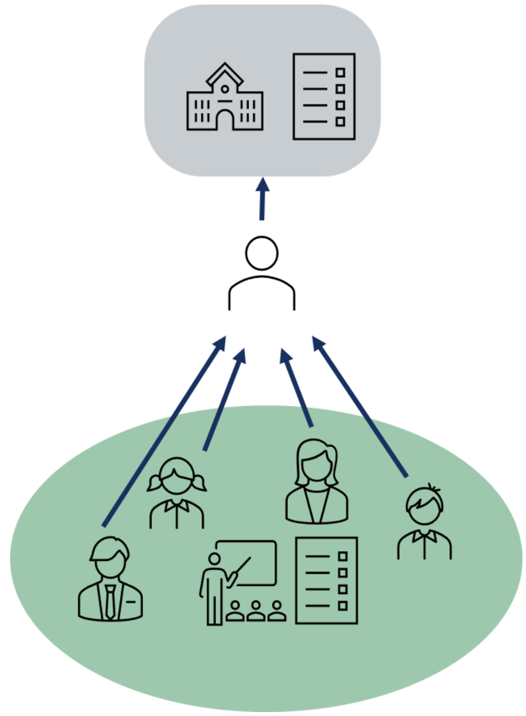


The support vector machines look for the division that is furthest away from both types of points. Therefore, the green division would be indicated by this method, being considered a more robust solution.

These methods have been described using only linear functions. However, each observed variable can be squared or its inverse, in order to model other types of relationships. We can also put the product of two variables, or any transformation. In general, we call this type of transformation kernel functions. This way, we are not limited to sharing space with a Hyperplane. We can have any other type of surface [108].

Lesson 4.3.5. Combine Learning

- Bagging
- Random Forest
- Stacking
- Boosting



Let's now think about methods to gather learning. It would be the equivalent in the classroom, having several students take the test, and obtaining a collaborative result from the students. Send the aggregated result as if it were done by one of the students.

We have the basic idea of sampling, bagging.

In this case we can obtain several functions h(x) based on random training sets. Even if fewer test cases, repeating K times, we are left with K functions h(x). These functions thus allow you to have a more robust result than using them. At the end we aggregate the result, usually the most frequent or the average.

The second way of trying to have multiple results and aggregate them changes the way we generate decision trees. The idea is to have a forest with K trees, not just one tree. Random forest. But then we have to generate decision trees, with some type of randomness. We can restrict the attributes to consider at each node. We randomly select a part of the attributes. Typically for a classification problem it will be the square root of the number of attributes. For a regression problem the value normally used is one third of the attributes.

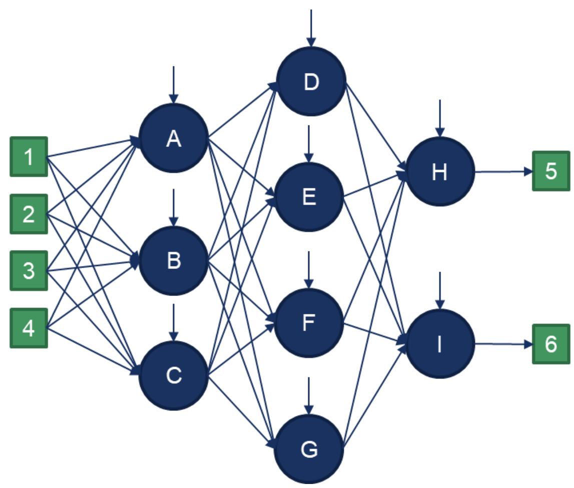
We run the algorithm normally, but for continuous variables, we only use some random cutoff points. The tree never stops trying to be great. Simply in each node it only considers part of the attributes. In each continuous attribute, it only considers some cutoff points. It is not necessary to prune the tree, as the added value of the forest will be used.

The third idea is to stack. Stacking. In this method we use K good functions h(x), which can have different natures. Instead of aggregating the data using the average, we add the value of these classifications to the x vector. Thus, each observation is increased with K classifications. We give this new vector to a learning method, which will make use of these values. If one of the methods has a perfect result, it will probably be used. In the most common case, you will certainly use a way to aggregate the values of the K functions.

Our final method of combining learning is amplification. Boosting. This is a simple method to try to eliminate negative cases. Whenever a case fails, it is cloned. There now exists one more copy. As a result, the method will be penalized more if it is not updated, thus potentially accelerating convergence [108].

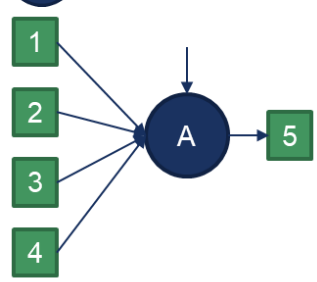
Lesson 4.3.6. Neural networks

- Dee learning
- Neuron
- Acyclic networks (NN)
- Train - Back-propagation
- Convulsive networks (CNN)
- Recurring networks (RNN)



Let's now talk briefly about neural networks. Neural networks are now the most comprehensive method of deep learning. Deep learning.

The reference to depth highlights the fact that each input data can be used several times before obtaining an output. In the network on the right, we have 3 levels, so there can be three types of interactions between the input variables, before the output.



The methods given previously did not require so many steps. Each node in the neural network was initially inspired by a neuron. It's basically a linear classification, with an activation function. We have already seen this method previously, in this case having 4 inputs, it will produce an output between 0 and 1. We use two activation functions. The cutting function and the logistics function.

The activation function is important, otherwise the linear data could just be multiplied but would never stop being linear. Thus, it is possible to model any type of function, as long as there are enough nodes in the network.

In a neural network, the result of the classifier is not final. It is input from classifiers at the next level. This way we can have different levels of concepts learned, before the network sends the final result for a given data input.

The basic neural networks are acyclic networks. It means that the connections do not go backwards. Each level is linked to the following levels. There is an input level, where all inputs are linked to these nodes. There is also a final output level, where each node is connected to an output.

Some type of normalization in continuous variables before entering the network may be beneficial, but is not critical. As for categorical variables, they have a value for each category, such as color. However, the categories have no order. Therefore, they are best described in one variable for each category.

In terms of outputs, in the case of continuous variables, we can omit the activation function at the last level, in order to output a continuous variable.

These networks can be trained, with the gradient descent algorithm. When calculating the value, the network is traversed from left to right. When moving to weight correction, the network is traversed from right to left.

The weights update is identical to that indicated in the linear classification. However, in nodes that are not the last, the error must be propagated backwards. The propagation of the error will change the weights so that the nodes that were in the right direction are more valued, and the others are penalized.

The network structure does not need to have this format. In the case of image processing, there are two more situations to take into account. There is the concept of neighborhood of pixels. This concept cannot be ignored, since a human being would also not be able to understand an image with scrambled pics. On the other hand, a feature found in one part of the image must be able to be found in another part. In other words, there must be spatial invariance. If it doesn't exist, simply take the photograph with a lag and the result will be completely different.

To solve these problems, convulsive networks emerge. This type of network starts by having a first level, in which each node is connected to a set of pics that are together in the image. There are nodes for each group of pixels, which will extract some characteristic. On the other hand, to guarantee spatial invariance, these nodes share the same weights. Thus, they will give the same result if a certain pattern appears in any area of the image.

The network can then develop other levels, maintaining the neighborhood concept. It is therefore not necessary for all nodes to be connected to all nodes at the previous level. This point is important to be able to parallelize operations on images. On the other hand, as the volume of data in terms of pics is very high, many weights would be needed for each node in the network, right at the first level.

Another important type of networks are recurrent networks. In these networks, the result of a node, can go backwards in the network. Naturally, the result will be used in the next iteration. This makes it possible for the network to process sequential data, maintaining information about the latest results. The possibility of connecting with a previous node adds the concept of memory to the network.

Audio or text processing, trying to find the next word, are examples of positive results obtained by networks of this type. Without memory, the neural network would have to be given the raw data all at once. A sentence, or audio file. The size of the sequence would be fixed. On the other hand, we would have to add some type of neighborhood, just like in convulsive networks. If this were not the case, it would be like analyzing the sentence with the words in random order. Recurrent networks thus allow the concept of sequence without a fixed dimension [108].

VIDEO 4.3.2. Introduction to Machine Learning - Learning from Examples - Part B [*duration 21:39 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=13899

Practical Assignments

Complete **Task 1**, **Task 2**, and **Challenge** described in the 3rd Topic "Introduction to Machine Learning: Learning from Examples" of the MOOC "Artificial Intelligence":

Task 1: Machine Learning: manual resolution:

https://open.ktu.edu/mod/page/view.php?id=10708

Task 2: Machine Learning automatic resolution:

https://open.ktu.edu/mod/book/view.php?id=17047

Challenge: https://open.ktu.edu/mod/page/view.php?id=10688

TOPIC 4.4. Natural Language Processing techniques

Learning Outcomes

By the end of this lesson on artificial intelligence, learners will be able to:

- Identify several tasks associated with Natural Language Processing;
- Perform topic modelling tasks using R;
- Develop procedures for storing word embeddings;
- Understand how Large Language Models work.

Topic Content

Introduction

Natural Language Processing is a set of techniques to imbue computers with the ability to understand and generate text or speech in human languages, based on 2 kinds of approaches:

- Symbolic: dictionaries and rules built by humans
- Statistical: using corpus-based data, including machine learning

NLP tasks:

- Part of speech tagging
- Sense disambiguation
- Named entity recognition
- Anaphora resolution
- Sentiment analysis
- Language generation

VIDEO 4.4.1. Introduction to Natural Language Processing [*duration 3:49 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=13473

Lesson 4.4.1. Topic modelling with Latent Dirichlet Allocation (LDA)

Topic modelling:

- To discover hidden topics/themes in text
- To classify documents according to the discovered themes
- To help organize/summarize/search the documents

Topic modelling methods:

- Clustering techniques: k-means, PCA, NNMF
- LDA (Latent Dirichlet Allocation)

Latent Dirichlet Allocation's main idea: each document can be described by a statistical distribution of topics and each topic can be described by a distribution of words.

VIDEO 4.4.2. Topic Modelling with Latent Dirichlet Allocation [*duration 4:56 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=13472

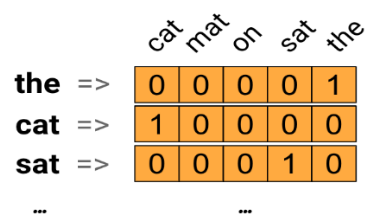
Lesson 4.4.2. Word embeddings with Word2Vec

Word embeddings:

Text representations where words are described by numeric vectors: proximity in vector space corresponds to proximity in meaning

“A word is characterized by the company it keeps” (Firth, 1957)

One-hot encoding



(Gupta, N.D.)

Key-feature: vector low dimensionality

Instead of bag-of-words, where words are undifferentiated, word embeddings capture meaning.

VIDEO 4.4.3. Word embeddings [*duration 1:52 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=16763

Lesson 4.4.3. Large Language Models

Language Language Models (LLMs) are:

- Large deep learning models trained on vast amounts of data
- Set of neural networks that extract meanings and learn relationships between words and frases
- Components/transformer architecture:
    - word embedding layer
    - feedforward layer
    - recurrent layer
    - attention mechanism

How to use **LLMs**?

- Training: usable models are already pre-trained with vast amounts of data, capturing general word meanings and relationships
- Fine-tuning: optimization of performance for specific tasks (e.g. translation)
- Specialized knowledge training: to adapt an LLM to a specific context

(*https://www.wisecube.ai/blog/a-comprehensive-overview-of-large-language-models*)

VIDEO 4.4.4. Large Language Models [*duration 1:54 minutes, created by the course authors*]: https://open.ktu.edu/mod/h5pactivity/view.php?id=16764

Practical Assignment

Complete **NLP related task** described in the 4th Topic “Natural Language Processing techniques” of the MOOC “Artificial Intelligence”: https://open.ktu.edu/mod/page/view.php?id=10693.

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