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IoT and Cloud for Sustainability

BIOS4YOU
AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS
THANKS TO THE USE OF AUGMENTED REALITY

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Contents

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General topic of the learning path	Big Data, IoT and Smart Cities for sustainable development
Specific name of the learning unit	Smart data for smart cities: digital technologies and SDGs
Age of the target users	14-18 years
Requirements for the learner	Basic digital skills (use of the cloud, data research, presentation tools). General knowledge of the environment, energy and global citizenship. Ability to work in a team and communicate effectively. Curiosity about technological innovation and social impact.
Description of the learning unit	This unit guides students in discovering the world of **Big Data**, the **Internet of Things (IoT)** and **Smart Cities**, with a strong link to the **Sustainable Development Goals (SDGs)**. Through **augmented reality** tools, simulations and collaborative projects, students analyse data, design solutions for smart cities and assess the impact of emerging technologies on urban quality of life and the environment. The course is divided into three phases: **Explore – Execute – Enhance**, integrating immersive activities and interactive formative assessments.
Subject: Parties involved	Computer Science, Technology, Civic Education, Geography, Science

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Keywords	Big Data, Internet of Things, Smart Cities, Cloud, digital skills, SDGs, urban sustainability, open data, digital citizenship, augmented reality, data literacy.
Key qualifications, skills and knowledge that can be acquired	• Understanding of the data life cycle: collection, processing, visualisation. • Ability to analyse datasets and draw operational conclusions. • Basic knowledge of IoT and urban digital infrastructure. • Collaborative design of smart solutions based on real data. • Awareness of the role of technology in sustainability processes. • Development of transversal skills: problem solving, critical thinking, digital communication.
Resources and didactic aids used	• AR platforms (e.g. CoSpaces Edu, Merge EDU, Assemblr, ZapWorks). • Public datasets (e.g. Eurostat, World Bank, regional open data). • Apps and simulators for visualising data flows, IoT networks, cloud infrastructures. • Online collaboration tools (e.g. Google Workspace, Padlet, Canva). • Educational videos, case studies and informative articles.
Assessment criteria and evaluation	• Understanding of Big Data, IoT, Smart Cities and SDGs. • Effective use of AR platforms, cloud tools and data analysis. • Quality, innovation and consistency of the project developed in a group. • Ability to identify sustainable objectives and propose targeted technological actions. • Clarity of presentation, correct use of technical language and multimedia supports. • Quizzes and AR dashboards for progress monitoring and continuous feedback from teachers and classmates.

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1. About Big Data

Big data refers to an enormous proportion of information data whose volume requires specific analysis methodologies and technologies for research purposes of any kind. The three fundamental characteristics of these information sets - the so-called three Vs - are:

- **Volume**. This is particularly voluminous data, implying that it is capable of taking up a lot of space, starting in the order of terabytes up to petabytes;
- **Speed**. Although the amount of data is particularly rich, it must be decoded and read in the shortest possible time. The determining factor for the handling and correct management of big data, therefore, is the speed.
- **Variety**. Big data are defined as unstructured or semi-structured data and this constitutes an additional difficulty, as preliminary analysis is required before they can be processed.

In even more recent times, other characteristics have been combined with the three Vs[1]:

- **Veracity:** In order for Big Data to be processed properly, it must be filtered; as it is raw data, it can lead to incorrect analysis and a high risk of statistical error and interpretation.
- **Value:** Not all big data may have value depending on the purpose for which it is processed and interpreted. Again, those of interest should be selected before analysis.
- **Variability:** They can be filtered, categorised and used in different ways according to the useful purpose.

There are generally three types of data: structured, semi-structured and unstructured. It must be emphasised, however, that data and information are not synonymous because - especially in computer science - information does not exist per se, rather it is retrieved through the processing of collected data.

When we speak of structured data, we mean a type of information that can be easily encapsulated and organised into data fields since it is characterised by a precise structure; to give an example, we can think of a table similar to this one, containing three different columns containing fields:

NAME	SURNALE	IDENTIFICATION CODE
Mario	Rossi	000000000001

When we speak of semi-structured data, we are referring to a type of information, part of which can be encapsulated in data fields - and is therefore structured data - while another section is made up of unstructured data; a case in point is that of e-mails, in which some fields are predefined, such as the sender, the addressee and the subject, while the body of the e-mail - i.e. the message we send - is in the form of unstructured data since it cannot be encapsulated in a specific field.

[1] https://searchdatamanagement.techtarget.com/definition/big-data

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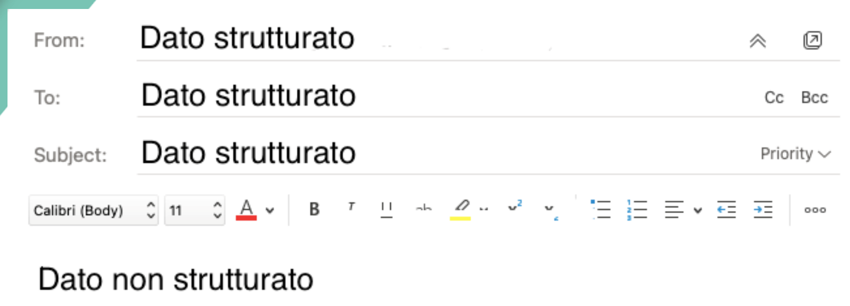

Figure 1 - Classification of data within an e-mail

As far as big data is concerned, it takes the form of unstructured, semi-structured and structured data.

2. What form do the data take?

Although it is now possible to exchange any format of data (e.g. photos, videos, documents, etc.) via digital means, it is not reflected that these are originally encoded through the binary system formed by the numbers zero and one. This system is based on a type of positional numbering, i.e. in which the position that the two numbers assume has its own importance and value; furthermore, since there are only two numbers used for encoding, the system is said to have base two. For all these reasons, the writing of a value in the binary system will have this form:

$$\mathbf{(001011)_2}$$

The subscript $_2$ testifies to the fact that it is a binary system, while the round brackets serve to contain the value. It is first possible to attempt to translate values in the binary system into values pertaining to the decimal system: to do this, it is necessary to order the values (the first will be the one at the far right and the last will be the one at the far left) and multiply them by two raised to progressive powers. For example:

1. We order the values from right to left

1	**1°**
1	2°
0	3°
1	4°
0	5°
0	6°

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1. Multiply each value by 2 to a progressively increasing power

1	2^0
1	2^1
0	2^2
1	2^3
0	2^4
0	2^5

1. We add up the results obtained from the individual multiplications

1*1	**1**
1*2	2
0*4	0
1*8	8
0*16	0
0*32	0
TOTALE	11

Ultimately, the value $(001011)_2$ in the binary system takes on a value of 11 in the decimal system. If, on the other hand, we wish to try the reverse operation, i.e. to transpose a number in the decimal system into one in the binary system, we need only divide the number progressively by 2 and take into account the remainder:

96

96/2 = 48	**0**
48/2 = 24	0
24/2 = 12	0
12/2 = 6	0
6/2 = 3	0
3/2 = 1	1
1/2 = 0	1

The number 96 in the binary system will therefore be:

$(1100000)_2$

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We can check that this calculated value is correct.

$0*2^0$	**0*1**	**0**
$0*2^1$	0*2	0
$0*2^2$	0*4	0
$0*2^3$	0*8	0
$0*2^4$	0*16	0
$1*2^5$	1*32	32
$1*2^6$	1*64	64
	TOTALE	96

The individual binary values contained within brackets are called bits and eight bits correspond to one byte. In the above case, for example, the sequence consists of seven bits.

The bit is a unit of measurement and therefore, like all others, has a scale of equivalence defined through the international system:

MULTIPLE	SYMBOL	EQUIVALENCE
Kilobit	kb	1000 b
Megabit	Mb	1000 kb
Gigabit	Gb	1000 Mb
Terabit	Tb	1000 Gb
Petabit	Pb	1000 Tb
Exabit	Eb	1000 Pb
Zettabit	Zb	1000 Eb
Yottabit	Yb	1000 Zb

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3. Where Big Data comes from?

Going back to the definition of the concept, it emerges how this type of data stands in contrast to traditionally processed data: first of all, the feature that most distinguishes big data from the rest is the complexity provided and the vastness of information it provides and, potentially, can produce. Big data, therefore, marks the overcoming of the storage and processing of data through relational databases.

DATABASE RELAZIONALI

The structure of a relational database takes the form of a table, within which rows and columns containing the data of interest are arranged. Each column has an attribute (or data field), containing all its unique values (e.g. product code sold by a supermarket), which are called records.

Cells 1A and 1B contain the data fields which, in this case, correspond to the identification code of each product and the units in the warehouse; cells 2A, 3A, 4A, 5A and 2B, 3B, 4B, 5B contain the records.
Supposing you have another table containing, instead, the product code and the units already on the supermarket's shelves, you can join this one with the previous table to obtain a third table containing all the data available to the supermarket: in this case, the join field between the two would be the product code.

	A	B
1	**Codice Prodotto**	**n. unità in magazzino**
2	ABABABAB	10
3	BCBCBCBC	5
4	CDCDCDCD	7
5	DEDEDEDE	16

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[2] https://searchdatamanagement.techtarget.com/feature/Big-data-collection-processes-challenges-and-best-practices

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navigazione, fornendo al fornitore di servizi la possibilità di memorizzare alcune informazioni sull'utilizzo del sito web, sulle preferenze di acquisto, etc. La funzione primaria dei cookies è, in ogni caso, quella di identificare l'utente e di *ricordare* quali siano le motivazioni della sua visita[3]: a fronte di ciò, essi sono diventati oggetto di preoccupazione da parte di alcuni consumatori. Tramite la Direttiva 2002/58/CE[4] del Parlamento Europeo e del Consiglio, relativa al trattamento dei dati personali e alla tutela della vita privata nel settore delle comunicazioni elettroniche, alla sezione delle considerazioni si spiega il senso dell'utilizzo dei cookies, sottolineando l'utilità di questo strumento e al contempo ammonendo i fornitori di servizi web, richiedendo di adottare criteri di trasparenza fornendo agli utenti informazione sulla tipologia di dati raccolti e sulle finalità d'uso. Successivamente, è entrato in vigore un regolamento sulla tutela della privacy, il *General Data Protection Regulation* (GDPR)[5], con il quale è stato introdotto – tra le varie misure – l'obbligo per il fornitore di servizi di non posizionare alcuno strumento di raccolta dati al primo ingresso da parte dell'utente, al quale viene poi richiesto il consenso per alcune finalità di utilizzo dei cookies (tecnici, cessione a terze parti, etc.).

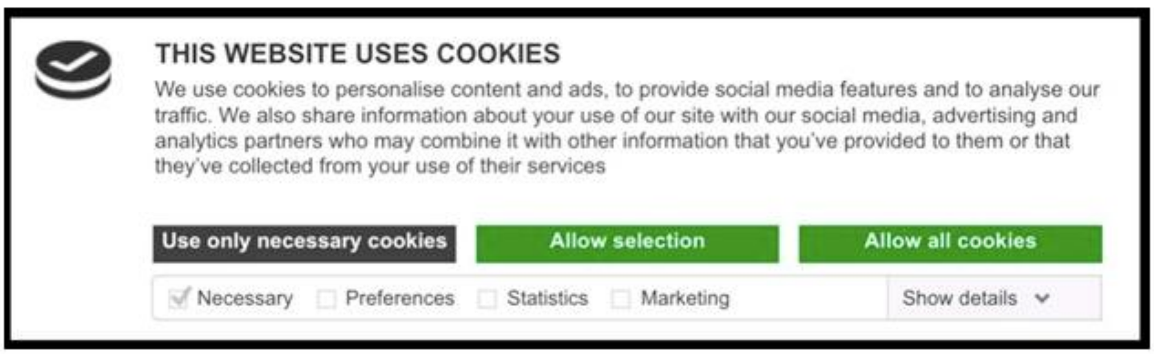

Figure 2 - Banner for consent to the use of cookies, source: https://www.neting.it/blog/cookie-law.html

In addition to cookies, various types of data can be obtained through social networks or through the use of sensors contained within devices belonging to the Internet of Things (IoT) world. Especially for the latter category, it is possible to access a multitude of data concerning the most diverse variables.

According to an AGCOM estimate, in 2018 alone, 28 Zettabytes of data were produced, the equivalent of 250,000,000 DVDs. Assuming that this amount of data were to be stored on memory disks with a capacity of one Terabyte each, approximately 3,006 477 $\times 10^{10}$ memory disks would be needed, which is an extremely large number even to imagine. According to another estimate, by 2020 each inhabitant of the Earth will generate an average of 1.7 MegaBytes of data per second, resulting in a total flow of 2.5 quintillion bytes of data per day.

[3] https://www.digitaltrends.com/computing/history-of-cookies-and-effect-on-privacy/
[4] https://eur-lex.europa.eu/legal-content/IT/ALL/?uri=CELEX%3A32002L0058
[5] https://eur-lex.europa.eu/eli/reg/2016/679/oj

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These magnitudes are even more surprising if we consider, for example, the amount of data that is produced in a single minute by some of the digital tools we most commonly use. To this end, it is useful to refer to the infographic in (Fig.3):

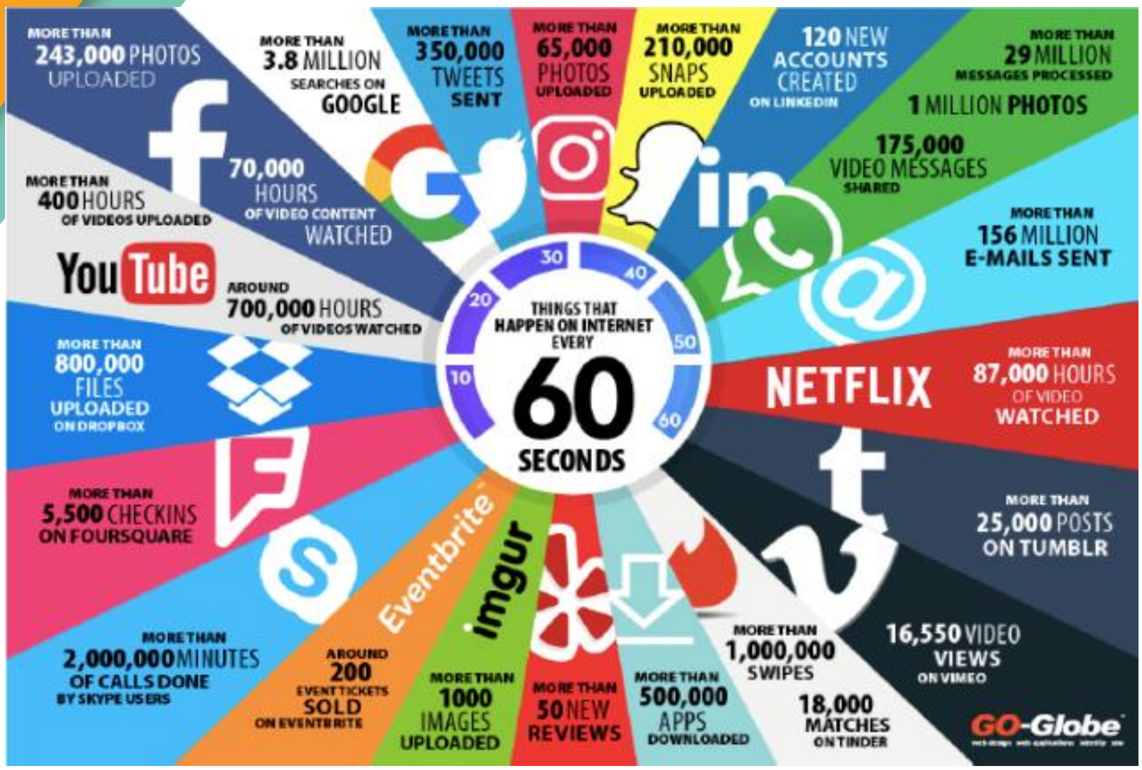

Figura 1 - Dati prodotti in un minuto, fonte: https://www.go-globe.com/things-that-happen-every-60-seconds/

However, although these quantities may already be particularly complicated to understand and imagine, it should be emphasised that the amount of data in ZettaBytes produced for each year is growing, as this graph produced by AGCOM shows:

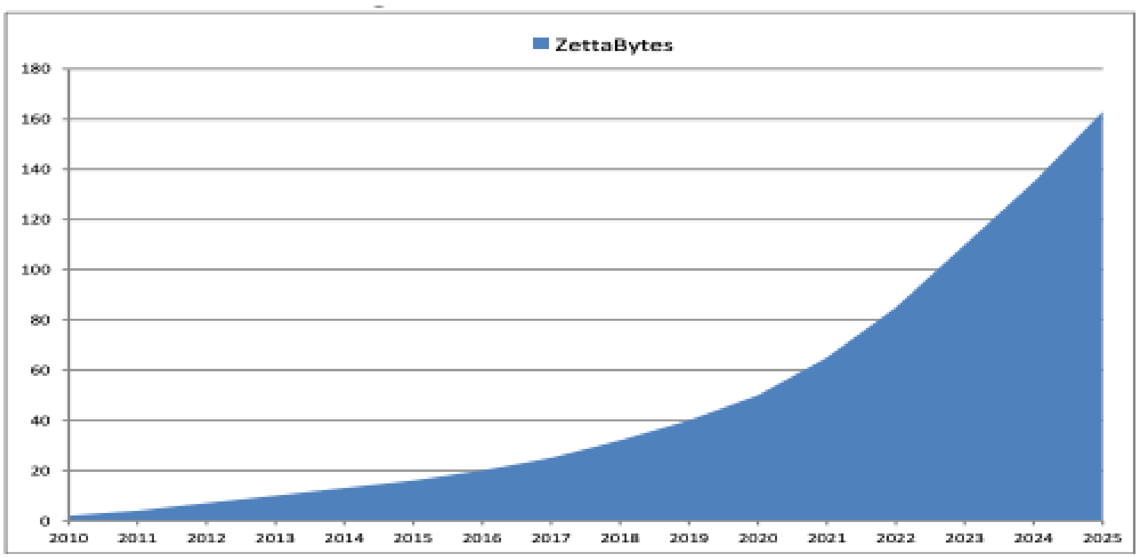

Figure 4 - Estimated amount of data in Zettabytes per year, source: https://www.agcm.it/dotcmsdoc/allegati-news/IC_Big%20data_imp.pdf

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4. Internet of Things

The Internet of Things (IoT) was conceptually born in the early 1990s, however, the first device to feature this technology was produced in 1999 at the Massachusetts Institute of Technology. The Internet of Things is understood to be the latest era - at the time - of the Internet in which certain existing properties of the Internet infrastructure were exploited to enable devices to connect to each other (Khanna, Kaur, 2019). According to Botta et al. (2016), the Internet of Things is and will increasingly be the main source of big and rich data: in fact, it is estimated that in 2011 the number of IoT-connected devices exceeded the number of Earth's inhabitants, while by 2020 it was assumed that more than twenty-four billion devices could be active.

THE FIRST EXAMPLE OF AN IoT DEVICE

The first device that could be classified as part of the Internet of Things was a webcam, which went down in history as the Trojan Room Coffee Pot.
At the University of Cambridge, England, some of the lecturers used to work in a room called the Trojan Room: there was a coffee machine outside and many colleagues would go there to enjoy a hot cup of coffee. However, often, some of these lecturers would walk inside the faculty to enjoy the coffee but, once they arrived, they would find that the carafe had already been emptied. To compensate for this inconvenience, some of them decided to install a video capture card in front of the coffee machine, created a client and also took care of the server: each colleague was then able to display in a small window a black and white image of the carafe, whose picture was updated three times a minute. In this way it became possible for everyone to know the right moment to walk to the coffee machine.

Figura 2 - Quentin Stafford-Fraser - Trojan Room Coffee Pot biography, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1313558

The full story is available at: https://www.cl.cam.ac.uk/coffee/qsf/coffee.html

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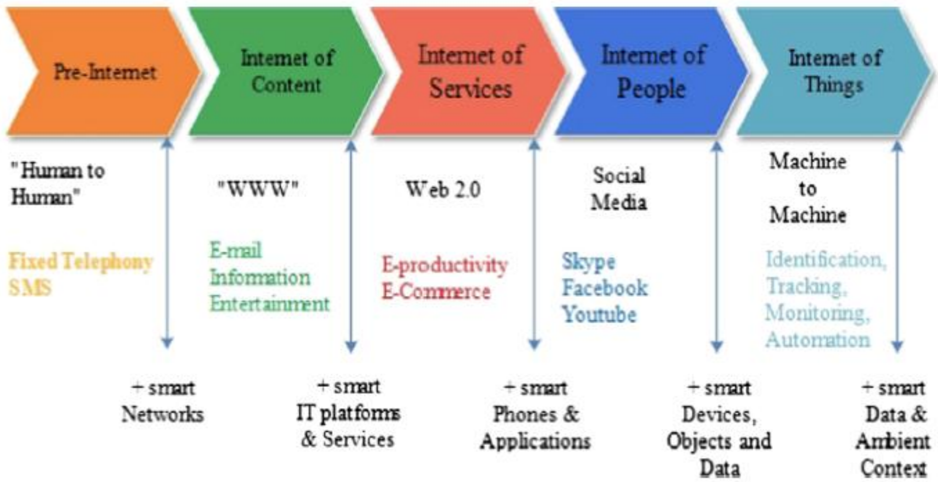

Figure 6 - Transition to IoT (Khanna, Kaur, 2019, p. 222)

The history of the Internet can be summarised in four main stages, the first of which is the one defined as the Internet of Content: in this first segment, there is the revolution in the world of communication thanks to the possibility for users to be able to use the infrastructure to exchange information thanks to e-mail and web pages. The second part of the transition towards the IoT is the Internet of Services, inaugurated by the emergence of e-commerce; later, thanks to the advent of social networks and other services aimed at implementing communications, such as Skype, the Internet of People was spoken of. The last phase of this process, as well as the current era of the Internet, can be identified in the advent of the Internet of Things, i.e., the possibility of connecting several devices together via the Internet in order to share information and data concerning various variables.
The IoT sectors are varied and include smart homes and home automation, wearables (hearing aids, visual aids, etc. or, for example, fitness trackers), smart grids (reading, managing, etc. the meters of domestic utilities such as water, electricity and gas supply), connected cars, industrial internet (remote control of industrial plants and machinery), and smart cities. The IoT applies to objects that have traditionally been purely analogue (e.g. clocks) but which, thanks to digital implementation, obtain greater performativity and the ability to perform additional functions.

Figura 3 - Varietà dell'Internet of Things

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5. How IoT technology works

Crucial characteristics of the IoT infrastructure are:
- The fact that each object possesses a unique identification code;
- The ability of devices to interconnect with each other via the Internet infrastructure to exchange up-to-date data in real time.

For networked objects to be able to communicate with each other, it is necessary that they contain within them technologies that allow them to be recognised and connected to other devices. Some technologies that operate in this sense are, for example:

- ***RFID (Radio-Frequency IDentification)***. Si tratta di una tecnologia basata sulla propagazione di onde elettro-magnetiche che permettono al dispositivo di essere rilevato e di inviare informazioni al lettore[6]. Gli unici oggetti che non possono contenere un tag RFID sono quelli costituiti all'esterno da metalli poiché, a causa della cosiddetta *gabbia di Faraday*[7], non riuscirebbero a rilevare le onde elettro-magnetiche.
  Questa tecnologia è particolarmente apprezzata dato che permette la tracciabilità del prodotto durante il suo intero ciclo di vita: infatti, non soltanto è possibile per il rilevatore leggere il contenuto (e, pertanto, i dati) prodotti e contenuti all'interno dell'oggetto, ma anche iscriverne di nuovi. Questo meccanismo fa sì che, ad esempio, il prodotto possa essere dotato di una sorta di *etichetta parlante* e contenente tutti i dati utili non soltanto alla sua rilevazione, ma anche al suo intero ciclo di vita[8]. Tag come quelli impostati secondo tecnologia RFID non necessitano di alimentazione; tuttavia, ne esistono anche alcuni a batteria (Botta et al., 2016).
  Esempi di tecnologia RFID nella quotidianità sono le placche antitaccheggio applicate sui capi di abbigliamento all'interno dei negozi, oppure i microchip per il censimento e riconoscimento degli animali domestici.

[6] https://www.rfidglobal.it/tecnologia-rfid/#Concetti_base

[7] Per comprendere il significato di *gabbia di Faraday* si rimanda al video prodotto da Zanichelli e disponibile al link: https://www.youtube.com/watch?v=ZEMA31_Bs-4

[8] https://www.rfidglobal.it/tecnologia-rfid/#Punti_forza

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Figura 4 - Un esempio di RFID nel quotidiano

- ***WSN (Wireless Sensor Network)***. This is a sophisticated technology whose impact on everyday life will be particularly significant, especially from an environmental sustainability perspective.

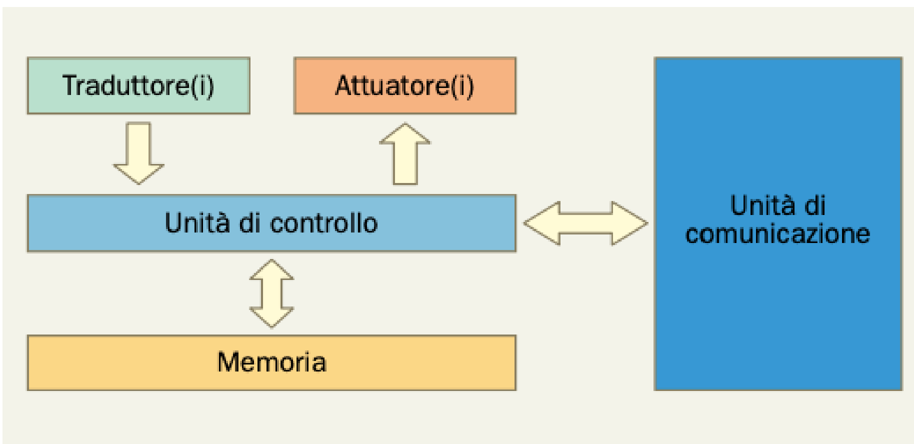

Figure 9 - WSN operating system (Zanella, Zorzi, 2006, p. 105)

The WSN system is based on the interconnection between five functional blocks, namely the transducers, the actuators, the control unit, the memory and the communication unit (Fig. 7). The transducers can be likened to sensors capable of detecting different types of quantities, such as temperature, humidity percentage, etc. They transmit the collected data to the actuators. They transmit the collected data to actuators, which have the ability to act on the environment in which they are located. An example of this exchange of information could be that of a smoke detector (transducer) which, by detecting the presence of carbon dioxide in the air, informs the actuator of this eventuality; the actuator could then sound an alarm.
The unit that acts as a bridge between transducers and actuators is the control unit, which has the ability to transform the transducer's electrical signal into a digital signal that can be read by the actuator's software. The memory blocks, on the other hand, house the executable code of the operating system and the application, as well as the data acquired from the sensors and processed by the application (Zanella, Zorzi, 2016, p. 106). Finally, the communication unit

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allows all the components of the functional block to establish communication, identifying radio waves as the preferred channel.

6. The Cloud

According to the definition provided by IBM, cloud computing is a service that allows on-demand access to applications, servers, etc., through the use of the Internet infrastructure. These resources are stored within data centres, i.e. physical structures within which data are stored on clouds; moreover, the functions of a data centre can be briefly described as:

- ***Computing,*** as they act as memory and processing centres;
- ***Storage,*** since they contain devices capable of backing up data;
- ***Networking,*** as they house routers, firewalls, etc.

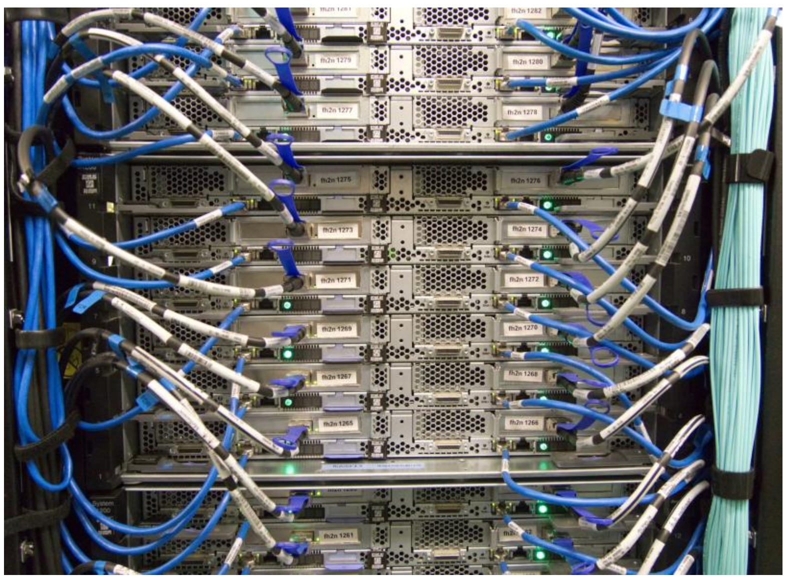

Figure 10 - An image of a data centre

The success of clouding and data centres can be attributed to the fact that they allow for cost-efficient provision of services via the Internet. However, from an environmental point of view, it is necessary to take into account the fact that infrastructures of this type require a great deal of electricity, both for powering and operating functions and for the cooling of environments.
With respect to the interaction between IoT and Cloud, both have characteristics that make them complementary and thus have the potential to further enhance innovation and service quality:

[9]	*IoT*	*Cloud*
Displacement	Pervasive	Centralised
Accessibility	Limited	Ubiquitous

[9] Translation of Table 1 in Botta et al., 2016, p. 10.

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Components	Things of the real world	Virtual resources
Computational skills	Limited	Virtually illimited
Storage	Limited or absent	Virtually illimited
Role of the Internet	Point of convergence	Means of reaching the service
Big Data	Source	Means of management

The integration of Cloud and IoT technologies is called CloudIoT and ushers in a new season of innovations in technology, capable of improving the performance of various agents and devices, and even making sectors that maintain a more traditional approach more efficient. Among the various sectors for which a CloudIoT system is adaptable, it is worth mentioning:

- Medicine;
- Environmental monitoring;
- Smart Cities;
- Smart Home;
- Etc.

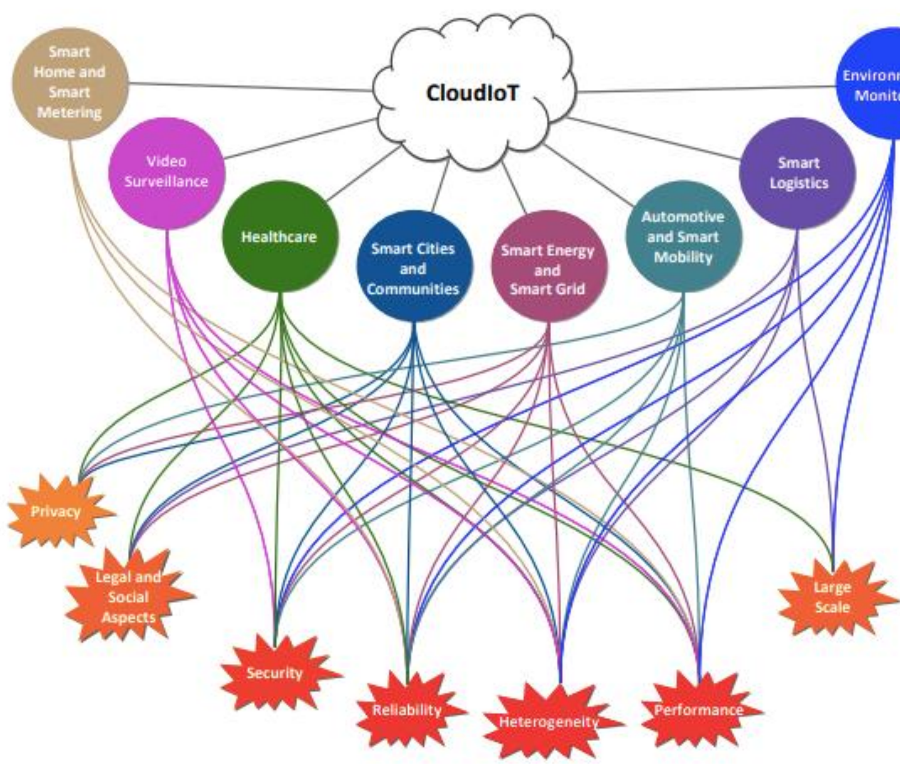

Figure 11 - Areas of CloudIoT application, source: Botta et al., 2016, p. 23

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6. Digital skills

In 2006, the Council and the European Parliament issued a recommendation on key competences for lifelong learning. The acquisition of these competences - among many other aims - is intended to ensure that European citizens improve their ability to develop personally, to find their place in the labour market and to stimulate social inclusion and active citizenship. Particularly in a globalised world, access to good quality education proves to be a particularly effective and desirable tool for the redistribution of wealth; moreover, society is changing and with it the skills of citizens should adapt, so that they can always respond promptly to the changes imposed by climate change and the need for innovation. In this context, digital skills take on added importance, firstly because it is estimated that around 90 per cent of job positions require some level of familiarity with technology and the digital world[10].
The European framework on key competences for lifelong learning defines eight main and desirable skills:

- Communication in the mother tongue;
- Communication in the foreign language;
- Mathematical competences and basic competences in the fields of science and technology;
- Digital competences;
- Learning to learn skills;
- Social and civic competences;
- Capacity for initiative and entrepreneurship;
- Cultural awareness and expression.

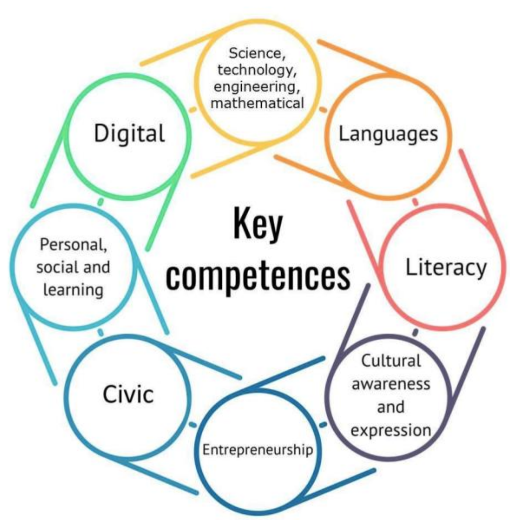

Figure 5 - https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018SC0014&from=EN

[10] Proposal for a Council Reccomendation on Key Competencies for Longlife Learning, 17/01/2018, p. 3, al link: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018SC0014&from=EN

The digital competence framework 2. 0 identifies the key digital competence skills and classifies them according to five macro-categories: information and data literacy, i.e. the ability to navigate through the mass of information available to us, filtering and correctly interpreting the information and data we are presented with; communication and collaboration, i.e. the ability to relate to other members of society via digital tools and to manage one's digital identity, as well as reputation digital content creation, i.e., the ability to create and edit content that can be made usable while respecting copyright laws; security, i.e., the ability to protect one's digital environment, as well as one's psycho-physical health, and to be able to understand the environmental impacts generated by digital technologies; problem solving, i.e., being able to solve any problems arising from the use of devices and to have the ability to innovate.
Each macro-category includes further specific competences according to the relevant axis; therefore, a total of twenty-one digital competences useful in the context of lifelong learning and the sustainability of European development are identified.

1- Information and data literacy	1.1. *1.1. Browsing, searching and filtering data, information and digital content* The ultimate goal is to be able to adopt one's own strategy to search.
	1.2. *1.2. Evaluating data, information and digital content* The ultimate goal is to be able to critically analyse and evaluate the available resources.
	1.3. *Managing data, information and digital content* The competence requires one to be able to organise and process information in a structured environment.
2- Communication and Collaboration	*2.1 Interacting through digital technologies* Interacting through digital technologies.
	2.2. *Sharing through digital technologies* Being able to share data, information and digital content through the available media, being able to use the rules of referencing and attribution.

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	2.3. *Being active citizens through digital technologies* Being an active citizen involves the ability to participate through public and private digital tools, as well as seeking opportunities for self-empowerment through technological devices.
	2.4. *Collaborating through digital technologies* It is the ability to use digital tools and technologies for collaborative processes.
	2.5. Netiquette Knowing the behavioural norms to be adopted in a digital environment.
	2.6. Gestire l'identità digitale Essere capaci di mantenere alta la reputazione della propria identità digitale e saper gestire il flusso di dati generato attraverso l'utilizzo dei dispositivi digitali.
3- Creazione di contenuti digitali	*3.1. Sviluppare contenuti digitali* Essere capaci di esprimere se stessi tramite la creazione di contenuti digitali.
	3.2. Integrare e rielaborare contenuti digitali
	3.3. Copyright e license Capacità di comprendere come il diritto d'autore e le licenze si applichino a dati, informazioni e contenuti digitali.
	3.4. Programmare Essere in grado di definire le azioni da fare svolgere al *device* in modo da risolvere un problema specifico o svolgere una mansione specifica.
4- Sicurezza	*4.1. Proteggere i dispositivi* Capacità non soltanto di riconoscere rischi e minacce provenienti dal mondo digitale, ma anche di distinguere quali siano le migliori misure di sicurezza da mettere in campo a tutela della propria privacy.
	4.2. Proteggere i dati personali e la privacy Ad esempio, la capacità di comprendere le privacy policy che i servizi digitali adottano per la gestione dei nostri dati.
	4.3. Proteggere salute e benessere

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	La capacità di evitare le eventuali problematiche psico-fisiche derivanti dall'uso e abuso dei contenuti digitali, nonché dall'odio online.
	4.4. Proteggere l'ambiente La consapevolezza dell'impatto ambientale delle tecnologie digitali e del loro utilizzo.
5- Problem solving	*5.1. Risolvere problemi tecnici*
	5.2. Identificare bisogni e risposte tecnologiche Vagliare bisogni e identificare possibili risposte tecnologiche per colmarli, oltre a personalizzare i propri dispositivi in base alle proprie esigenze.
	5.3. Usare i dispositivi digitali in modo creativo Essere in grado di utilizzare gli strumenti digitali per creare conoscenza e innovare processi e prodotti.
	5.4. Identificare i gap nelle competenze digitali Cercare opportunità per lo sviluppo personale e tenersi al passo con l'evoluzione del mondo digitale.

7. Big Data e SDGs

The 2030 Agenda adopted by all United Nations Member States defines seventeen goals called *SDGs*, *Sustainable Development Goals*. Launched in 2015, it commits the signatory states to achieving certain goals. The seventeen goals can be listed below, bearing in mind that they encompass a total of 169 targets:

- ***Zero poverty***, with the aim of ending all forms of poverty in the world;
- ***Zero hunger***, ending hunger and achieving food security, improving nutrition and promoting sustainable agriculture;
- ***Good health and well-being***, ensuring health and well-being for all, regardless of age;
- ***Quality education***, ensuring equitable and inclusive access to education and promoting learning for all;
- ***Gender equality***, closing the gender gap and empowering women;
- ***Clean water and sanitation***, ensuring access to this precious and essential resource for all, while adopting a sustainable approach to its management and that of sanitation facilities;
- ***Affordable and clean energy***, ensuring that everyone has access to sustainably produced electricity without neglecting the economic aspect;
- ***Decent work and economic growth***, promoting sustainable, inclusive and sustainable economic growth, ensuring decent employment for all;
- ***Industry, innovation and infrastructure***, promoting fair, responsible and sustainable industrialisation through innovation;
- ***Reducing inequalities***, both within and between countries;
- ***Sustainable cities and communities***, making territories, at all scales, inclusive, safe, resilient and sustainable;

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- ***Responsible consumption and production***;
- ***Climate action***, promoting actions to combat climate change, involving all levels of governance;
- ***Life below water***, conserving oceans, seas and marine resources to ensure a sustainable path to development;
- ***Life on land***, through the protection, restoration and promotion of the sustainable use of terrestrial ecosystems;
- ***Peace, justice and strong institutions***;
- ***Partnerships for the goals***, strengthening the global partnership for sustainable development.
- As can be seen, all these goals have been drawn up using an integrated approach centred on the so-called "Five Ps", namely People, Prosperity, Peace, Partnership and Planet.

Figura 6 – The five P, source: ONU

8. Smart cities

In recent years, the concept of the smart city has gained widespread popularity, referring to a model of urban innovation capable of exploiting the functions of the digital world and data obtained through IoT technologies to improve public services such as healthcare, mobility, water supply quality, etc., while raising the quality of life for citizens and city users. In general, the smart city model is linked to characteristics inherent in resilience, sustainability, governance, service and resource management, as well as improving the quality of lifestyles and life itself (Al Nuaimi et al., 2015).

In this perspective – and in order to achieve these goals – the importance of Big Data, IoT technologies and the integration between the two is clear: in fact, the key themes of smart cities can be implemented through the acquisition of data, its storage and, finally, its processing for decision-making, i.e. the process of making decisions (e.g. improving urban mobility infrastructure, etc.). One of the clearest definitions of what is meant by smart cities is: “The connection between physical, IT, social and economic infrastructure to harness the collective intelligence of the city” (Chourabi et al., 2012). From this, it is therefore possible to arrive at the logical framework underlying the concept itself and define its operating criteria:

- As already discussed, data flows can be produced from a huge number of different sources, such as social networks, purchase transaction data, etc. This Big Data can also be obtained through IoT technologies;
- Sensors embedded in IoT devices generate additional data flows which, once processed, can provide information about the environment and people: think, for example, of cameras active in urban areas, traffic detection sensors, air quality sensors, etc.;
- In order for all these flows to be stored and made available for processing – through which the decision-making phase can then be reached – the Cloud is the tool of choice because, as already mentioned, it is an economically sustainable and reliable system;
- Through data processing – or data analysis – it is possible to understand what decisions to take in urban areas to streamline government and land management actions and, at the same time, improve the quality of life for everyone.

A practical example of how these technologies can make a city smarter and more functional is traffic management: given the high number of individuals gravitating towards urban areas, the integration of Big Data, IoT and the Cloud can support the definition of strategies that can be adapted in real time to mitigate the negative effects of congestion and the resulting pollution. In this case, sensors can collect traffic data which, once processed, can give instructions to actuators in traffic lights and other objects so that they can streamline activities and intervene to prevent congestion and other negative externalities.

9. Augmented Reality (AR) Integration

Students use AR devices to explore a virtual urban environment where thousands of sensors collect data: air quality, noise levels, energy consumption, temperature, traffic. With a simple gesture or voice command, these values are superimposed on the real environment of the school or their city, making the dynamics that connect technology and sustainability tangible. The data can be historical or real-time, simulating the functions of a smart city and showing, for example, how a smart irrigation system reduces water consumption compared to a traditional one.

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Divided into teams, they design **prototypes of sustainable IoT systems** (such as greenhouses with humidity sensors, smart home energy saving systems or environmental monitoring devices for schools), which can be viewed and tested in AR. For example, students can modify the parameters of a CO_2 sensor and observe in real time how environmental levels or energy consumption change in a smart home.

The experience is enriched with advanced **augmented simulations** and **gamified challenges**: in an interactive smart city, students must collaborate to reduce the environmental impact of a neighbourhood by choosing where to place sensors, optimising energy and data flows in the cloud and observing the evolution of environmental conditions.

10. Conclusion: The Future of AR in Vision Science

Integrating Augmented Reality (AR) into bio-inspired vision research transforms how students learn, experiment, and innovate. Through immersive 3D simulations, interactive visual mapping, and AI-powered analytics, AR bridges the gap between biological vision science and engineered optical systems.

By experiencing hands-on AR-enhanced learning, the next generation of scientists and engineers will be better equipped to develop advanced bionic vision technologies, AI-driven robotic sensors, and augmented optical interfaces, shaping the future of bio-inspired innovation.

Phase	Description
Explore	Introduction to the concept of Big Data: volume, variety, velocity. With the help of augmented reality (AR), students visualise how large data streams are collected, analysed and used in the real world. Through immersive examples, they explore the difference between structured, semi-structured and unstructured data in AR, simulating the transformation of raw data into useful information. They use 3D models and augmented concept maps to trace the main sources of data (digital devices, social media, sensors, online transactions). Assessment of initial digital skills through AR quizzes and interactive workshops to tailor the teaching approach to students' prior knowledge.
Execute	Design smart environments in AR (e.g. connected home, digital school), simulating data flows from sensors, actuators and mobile devices. Each group can modify parameters and measure the impact in real time. Simulate in AR how data is transferred, stored and processed in the cloud. They represent simplified cloud architectures in 3D to understand the concepts of SaaS, PaaS and IaaS. Analyse real or simulated data sets related to the Sustainable Development Goals (e.g. SDG 3 – Health, SDG 11 – Sustainable cities) and visualise them through AR graphs and dashboards. Each team proposes sustainable actions based on data analysis.

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Enhance	Interactive virtual environments (e.g. forests, coastal cities, power plants) to understand complex climate and energy systems. Modify energy parameters in their AR models (e.g. change energy sources or building materials) and visualise the effects on emissions or thermal comfort in real time. They accumulate points by solving interactive quizzes on the causes, effects and solutions of climate change and complete group design challenges, advancing to higher levels in the design of sustainable energy systems. 3D models with enhanced AR, answer dynamic quizzes and reflect on the future role of augmented reality in scientific, environmental and engineering understanding.

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BIOS4YOU

AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS
THANKS TO THE USE OF AUGMENTED REALITY

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