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IoT4Schools
"Bringing the Internet of Things in school education as a tool to address 21st century challenges"

- defining learning objectives and learning methodology for IoT projects -

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Scope of the document

This document defines the learning objectives and learning methodology for the development and design of learning scenarios revolving around the Internet of Things (IoT), setting also the foundations of the learning methodology for the IoT projects that will be developed in the context of WP3.

The identification of the needs underlying the introduction of IoT in secondary school education and the selection of pedagogical approaches that have been successfully employed in similar learning contexts have informed the development of both the learning objectives and the learning methodology. A brief literature review (presented in the 2nd section of the IoT4Schools handbook) was conducted in the field of IoT to identify the needs associated with the introduction of IoT in secondary school education. Furthermore, a number of implementation examples were identified, which helped to focus on pedagogies and learning approaches that have been successfully used in past cases, thus facilitating the smooth introduction of the topic of IoT in education.

For this purpose, a template was created and shared with partners, in digital format, with the intention of collecting their input and facilitating the recording and capture of different inspiring stories and good practices. A total of seven inspiring stories were compiled, each addressing a different instance of introducing and implementing IoT in educational settings. The initial outcomes of this process are presented in the first section of the present document, while a more comprehensive description is included in the Iot4Schools handbook.

The second section presents a number of learning objectives that are critical for the proper introduction of IoT in secondary education, while the third section presents a number of learning methodologies that can sustain this smooth introduction. The learning objectives and learning methodology serve to establish the framework for the development of the proposed learning scenarios, ensuring alignment with the needs and the scope of the IoT4Schools project.

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1. Input from partners – Sharing Inspiring Stories or Good Practices of IoT in Education

EDUMOTIVA's suggestions	
Inspiring story/ Good practice #1	In the UK, the Project Distance initiative, supported by Innovate UK, facilitated a collaboration involving ScienceScope—a company known for integrating technology into education—and various other entities including the University of Birmingham, UCL, Xively, Intel, among others. The project included eight schools, each outfitted with an environmental logging box filled with different oxides, a weather station, a general logger, and multiple sensors. These dataloggers were specially designed to send sensor data to a cloud-based IoT platform known as the Distance Exploratory, which was used for educational activities. ScienceScope continues to expand this program globally, applying the same framework in schools around the world Reference: https://www.womenofwearables.com/blogwrite/teaching-the-iot-at-schools-ideas-for-preparing-children-for-connected-and-intelligent-environments https://www.information-age.com/project-aims-to-put-the-internet-of-things-into-schools-28592/ https://www.besa.org.uk/news/sciencescope-ltd-distance-launches-internet-school-things-international-collaboration-focused-advancing-education-new-technology/
Inspiring story/ Good practice #2	The WeMakers Erasmus+ project revolved around designing, manufacturing, and programming intelligent objects, while introducing – among others – IoT in school education. Towards this direction, a number of learning scenarios included in "The educational IoT manual" were developed and proposed. One of them was "The fire management system in the forest". This learning scenario was about the creation of a system (comprised of a number of Arduino-based devices equipped with heat, smoke and IR sensors) that can detect fire in the forests and notify the corresponding authorities to act. Through this real-case scenario the students were introduced to robotics and IoT and how the latter can be implemented towards protecting the environment.

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WUT's suggestions	
Inspiring story/ Good practice #1	The IoT Club of the Academic Secondary School of the Białystok University of Technology implemented the "IoT = Ecology" project, as part of which it built two IoT devices. The first one was supposed to limit uncontrolled electricity consumption, e.g. turn off the TV when we fall asleep before it or turn off the bedside lamp when we fall asleep instead of reading a book. Falling asleep was to be monitored using a pulse oximeter, which determines when a person has fallen asleep based on blood pressure values. The second device was to help collect rainwater with appropriate parameters. Currently, many people install barrels to collect rainwater from gutters but do not check the quality of this water. Phenomena such as smog contribute to the formation of acid rain, the water from which should not be used to water plants. Hence, the project assumed the installation of pH and TDS sensors in the gutters to test the water quality. If the water has the correct parameters, it goes to the barrel, if not, the water stream is first directed to the reverse osmosis filters. *Source: https://projektanciedukacji.pl/projekt?id=19357*

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ATERMON's suggestions	
Inspiring story/ Good practice #1	An Erasmus+ KA2 school project named AI4STEM, aims to introduce primary and secondary education students to Artificial Intelligence through a combination of various hands-on IoT projects, programming, and STEM learning outcomes. The project was featured in the European School Education Platform in April 2024, as one of the most prominent projects to create value to educators and to build AI capacity of schools. Some of the IoT projects that are available include a Smart robotic car, an AI vision system, and a Smart intruder alarm, among others. The project comprises three main teaching components, an Educational Framework, a IoT Electronics Kit, and an online Academy. Source 1: https://ai4stem.erasmusplus.website Source 2: https://school-education.ec.europa.eu/en/insights/practices/adapting-future-responsibly-integrating-ai-teaching-and-learning
Inspiring story/ Good practice #2	SURF is a cooperative of Dutch educational and research institutions that collaborate to enhance digital services and foster knowledge sharing through continuous innovation. This collaboration includes universities, colleges, vocational institutions, UMCs (University Medical Centers), and research institutions. Together, they work to purchase or develop the best digital services. SURF (https://www.surf.nl/files/2020-01/iot-on-campus.pdf) is also exploring the potential of an Internet of Things (IoT) applications ecosystem specifically for the Dutch research and education community. Various research projects and pilots at universities and research institutes across the Netherlands are investigating ways to reuse and share network resources and data platforms for IoT applications. Some of these initiatives are highlighted below: 1. The Smart Campus in Groningen https://www.surf.nl/smart-campus 2. The Green Village in Delft https://www.thegreenvillage.org/ SPIN: Security and Privacy for Inhome Networks, from SIDN labs https://www.sidnlabs.nl/nieuws-en-blogs/spin-a-user-centric-security-extension-for-in-home-networks

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HERON's suggestions	
Inspiring story/ Good practice #1 **How White Mountains Regional High School Used IoT to Build an Automated Greenhouse**	High school students majoring in computer technology, environmental science and sustainability and mechanics and fabrication, at White Mountains Regional High School in New Hampshire, US, collaborated to build an internet-connected greenhouse. Led by teachers Dan Hubacz, Aidan Howry, and Dana Graham, students used remote sensing applications to automate lighting, regulate temperature, adjust humidity and monitor the greenhouse from their phones. Students who would not normally be in the same classrooms, collaborated on this exciting, interdisciplinary project and learned practical skills that they can apply in the future, such as connecting devices, automating manual processes and welding parts. However, this project offered students more than just practical skills. They enhanced their cooperation and communication abilities while also experiencing the excitement of learning and witnessing meaningful outcomes. https://www.youtube.com/watch?v=9dG8J7HrwKA https://cloud.arduino.cc/building-automated-greenhouse
Inspiring story/ Good practice #2 **Cyprus Space Week: *Inspiring the Next Generation of Space Scientists***	The Cyprus Space Foundation (CSF) collaborated with the Meteorology Department, the Eratosthenis Centre of Excellence (ECoE) at the Cyprus University of Technology, and the Excelsior2020 project to host the fourth annual Cyprus Space Week. This event aimed to promote space exploration and astronomy in Cyprus and foster international collaboration. As part of the program, the Pico microsatellite experiment involved launching a microsatellite using a weather balloon. On Friday, May 26, 2023, E.L.I.A.S., the robot of PASCAL English School (Larnaka) students, was launched on a spaceflight reaching an altitude of up to 90,000 meters. This

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	microsatellite faced extreme conditions at high altitudes, including sub-zero temperatures and intense solar radiation. Enclosed in microcapsules, the Pico satellite endured space-like environments. Once it landed, participating schools received the capsules, allowing students to analyze how space conditions affect seed growth in hydroponic systems. The microsatellite consisted of sensors and cameras that gathered information including speed, altitude, temperature, moisture, that were then used by students to analyse the changes based on the trajectory of the balloon. https://www.pascal.ac.cy/news/news/view/~board/larnaka-secondary/post/elias-from-pascal-space-center-achieved-a-successful-spaceflight

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2. Learning objectives

When introducing the IoT in schools, it is crucial to establish clear learning objectives that inform teaching practices and guide the achievement of learning outcomes.

a) Foster foundational knowledge of IoT concepts and technologies

This includes understanding how various devices collect, share, and process data to interact with the physical world. By grasping the principles of sensors, networks, and data analytics, students can comprehend how IoT devices contribute to the more efficient operation of a range of systems, including homes, cities, environment, health and transportation systems. Having acquired this knowledge, students can then proceed to examine in greater depth the issues related to the IoT sector.

b) Identify in which cases IoT systems are used and how these systems enhance various sectors of everyday life

This approach enables students to gain an understanding of the underlying needs of specific sectors and to identify the most suitable IoT technologies based on real-world case studies. Furthermore, this method fosters interdisciplinarity, enabling students to explore a diverse array of cases belonging to different fields and subjects where IoT can be applied.

c) Comprehend the impact that data-driven decisions can have in multiple real-world cases

It is essential that students are able to identify instances where data-driven decisions are made, as well as the most effective method for utilising raw data and extracting useful information based on specific parameters, in order to address a given problem, thereby creating a functional IoT system or application.

d) Cultivate practical skills in the design and implementation of IoT solutions

This involves hands-on experience with age-appropriate hardware and software, which encourages creativity while also facilitating experimentation. Such practices are also interlinked with the development of digital literacy, in particular the acquisition of skills such as the ability to use microcontrollers and electronic components, programming, and designing applications. The aforementioned skills will be predominantly developed through the IoT projects that will be developed in the context of WP3. Nevertheless, the current learning scenarios will stimulate students' interest in the types of hardware and software that can be employed in the production of IoT devices and systems.

e) Instil an understanding of the ethical, privacy, and security challenges associated with IoT

As students gain an understanding of the extensive capabilities of IoT technology, it is also important for them to be aware of the responsibilities that accompany the deployment of IoT devices, as well as the potential risks associated with sharing and storing data in the cloud.

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3. Learning methodology

Introducing the IoT into school classrooms necessitates thoughtful pedagogical planning to harness its educational potential. Teachers can employ specific methodologies and educational practices to introduce IoT in a manner that is both meaningful and engaging for students.

One effective methodology that can be put forward is **project-based learning (PBL)**, where students work on a project over an extended period of time – from 1-2 week(s) up to a semester – that engages them in solving a real-world problem or answering a complex question [1]. Through this process, they demonstrate their knowledge and skills by designing, creating, troubleshooting their own IoT-enhanced artefact or project [2]. An innovative aspect of PBL is that it pushes against teacher-centred practices and helps make learning meaningful and useful to students by establishing connections to life outside the classroom, addressing real world problems, and developing real world skills. Moreover, through this approach, students explore complex concepts by blending practical and theoretical aspects, which encourages critical thinking, problem-solving, collaboration, and a range of other essential skills [2].

The term "**critical thinking**" is used to describe the ability to view the world from a multiplicity of perspectives and to identify potential improvements [3]. This skill is developed over time and is strongly related to active learning [4]. In this context, reasoning skills are cultivated through IoT4Schools learning scenarios, which seek to engage students with everyday problems and challenges that require them to think logically, evaluate evidence, identify critical parameters and solve problems based on these processes.

The process of **problem solving** encompasses a range of learning methods, including assisting students in comprehending and investigating a problem, identifying solutions to emerging demands, evaluating outcomes (through self- and peer assessment), and, ultimately, fostering critical and high-order thinking skills [5]. However, if the problem is too vast, vague, or not aligned with students' personal interests, they may become easily discouraged and lose interest in the task at hand [6]. Consequently, it is crucial to provide a diverse range of tasks, enabling students to select the area of focus that best aligns with their interests. It is similarly important to pose questions to students that prompt them to search for answers, although these should not be unique.

Allowing students to work on **real-world problems** or choose **their own project topics** holds immense importance in education, particularly in fostering a deeper engagement with learning. When students are given the autonomy to select issues that resonate with them personally or are tasked with solving practical problems, they are more likely to be motivated and invested in the outcome of their work. This approach not only increases relevance but also enhances the learning experience by connecting classroom practice to tangible challenges outside the school environment.

Regarding **collaboration**, it is important to foster and embrace opportunities to work with one another or to work in teams. An IoT project comprises a number of distinct stages, including brainstorming, planning, creation, programming and sharing. The formation of teams allows students to consider how to approach their project, subsequently enabling them to allocate work based on individual preferences and skills. In this manner, the entire process becomes more engaging, and students perceive themselves as equally participating in the making process.

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Another promising method for the creation of learning scenarios and projects that align with students' personal interests is the enhancement of **interdisciplinarity** [7]. One approach that has gained considerable traction is the integration of science, technology, engineering, arts, and mathematics (STEAM) education. This approach encompasses a number of different subjects and disciplines, and is designed to foster a broader perspective on the skills that are developed and applied.

The learning scenarios developed for the IoT4Schools project seek to integrate the various methods previously outlined. In this context, the scenarios are designed to highlight an existing problem or challenge that students may encounter on a daily basis. Each scenario is recommended to be carried out in teams, with the objective of fostering collaboration and the exchange of ideas. To encourage hands-on practices and interactivity, an IoT application or device is suggested to be used. Each team will collect data for a specific period of time and will analyse and reflect on the received data. Based on the results, the team formulates and designs feasible solutions for the given problem. The results of this phase are presented in the plenary session in order to foster interactivity and discussion with other teams.

In brief, the suggested step for introducing a learning scenario in the classroom are:

1) Group Formation: Form teams to foster collaboration and diverse viewpoints
2) Device Integration: Each team is assigned a smart device to work on data collection
3) Data Collection Assignment: Over a period of time students record data
4) Analysis & Reflection: Teams maintain a diary of their observations, noting any trends, anomalies, or patterns
5) Presentation & Discussion: Teams present their findings in a class discussion, highlighting insights and personal experience

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4. References

[1] Thomas J.W. (2000) “A review of research on Project-Based Learning”, PhD research Supported by the Autodesk foundation, available online: http://www.bobpearlman.org/BestPractices/PBL_Research.pdf

[2] George S. and Leroux P. (2001). Project-Based Learning as a Basis for a CSCL Environment: an Example in Educational Robotics, First European Conference on Computer-Supported Collaborative Learning (Euro-CSCL 2001), 2001, Maastricht (Netherland), Unknown Region, pp.269--276

[3] “How to teach critical thinking – Benefits & Approaches”, study.com website (accessed June 2024 at https://study.com/academy/lesson/teaching-critical-thinking-skills.html)

[4] “Helping Students hone their critical thinking skills”, eduTopia official website (accessed June 2024 at https://www.edutopia.org/article/teaching-critical-thinking-middle-high-school/)

[5] Papasarantou, C., Alimisi, R. and Alimisis, D. (2023) “Virtual Galleries as Learning Scaffold for Promoting Problem-Based Learning”, MDPI journal - Educ. Sci., Vol. 13, Issue 12, 1168, https://doi.org/10.3390/educsci13121168

[6] “How Students Can Rethink Problem Solving” eduTopia official website (accessed June 2024 at https://www.edutopia.org/article/strengthening-high-school-students-problem-solving-skills/)

[7] “Connecting across disciplines in PBL”, eduTopia official website (accessed June 2024 at https://www.edutopia.org/article/interdisciplinary-project-based-learning)

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