DIGIWATER

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DIGITALISATION OF WATER INDUSTRY BY INNOVATIVE GRADUATE WATER EDUCATION (DIGIWATER)

WORK PACKAGE 2 – DIGITAL WATER CURRICULUM

T2.2.2 – DEVELOPMENT OF PRACTICAL ASSIGNMENTS

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1. INTRODUCTION

1.1. GENERAL

Water is an irreplaceable resource and has a global value because of the role it plays in improving the economy, society and the environment. The European Commission works towards linking the physical and digital world for water solutions tackling the societal challenges of water availability, quality and climate-change-related impacts, while the water industry goes through a digital revolution.

"Digital Water[1]" is an important concept underpinning the Water Europe Vision, based on the predicted development of a world where all people, "things" and processes are connected through the "Internet of Everything", leading to capillary networks and sensors, meters and monitoring of the water system all the way along to the individual user, as such generating large amounts of valuable data for innovative Decision Support and Governance Systems. "Digital Water" is now seen not as an 'option' but as an 'imperative'.

The DIGIWATER project aims:

a) To develop new, innovative and multidisciplinary approaches to teaching and learning by using multidisciplinary curricula integrated with digital learning tools and virtual facilities like sharing of labs/software with access in cloud systems and Problem Based Learning,

b) To stimulate entrepreneurship and entrepreneurial skills of higher education teaching staff and company staff using Innovation Camps, and,

c) To facilitate the exchange, flow and co-creation of knowledge by creating inter-stakeholder courses integrating academic, corporate learning and professional development for external specialists.

DIGIWATER focuses on how to achieve these goals through better preparation of the decision makers, the innovators and engineers of tomorrow, by utilizing the collaboration of six universities and six SMEs from Belgium, Cyprus, Germany, Norway, Romania and Turkey.

Seven Target Groups (TGs) will benefit from the results and the outcomes of the project; the future water professionals (TG1), the water professionals (TG2), the water educators (TG3), the technology entrepreneurs (TG4), the local communities, (TG5), the water industry (TG6) and the European community at large (TG7). TG1, TG2, TG3 and TG4 will be involved into direct project activities and

[1] International Water Association, 2019
https://iwa-network.org/publications/digital-water/

development, TG5 will actively participate in processes for the co-creation of regional policy initiatives via innovative camps, and TG6 and TG7 will be reached via dissemination and exploitation activities.

1.2. OBJECTIVES

The Project comprises of seven Work Packages (WPs) as follows:

- WP1: Digital Water Needs Analysis
- **WP2: Digital Water Curriculum**
- WP3: Digital Water Living Lab
- WP4: Internal Quality Assurance
- WP5: External Evaluation
- WP6: Dissemination and Exploitation of results
- WP7: Project Management

WP2 aims to upgrade the water curricula with digital subjects and embed training on innovation and entrepreneurship. The objectives of WP2 are:

i. To design a curriculum relevant to the market and societal needs.
ii. To develop teaching and learning materials that can be used in universities or in courses both in class and via e-learning.
iii. To design and develop an e-learning platform.
iv. To train teachers in academia and companies.
v. To implement the upgraded curricula in partner universities.

The curricula will be developed for two subjects: (i) IoT & Big Data, and (ii) Cybersecurity in Critical Water infrastructure.

The objectives of WP2 are to be achieved through the implementation of the following tasks:

1. T2.1.1: Analysis of partners' assets
2. T2.1.2: Best practices review
3. T2.1.3: Digital Water curriculum design workshop
4. T2.1.4: Design and planning of syllabi
5. T2.2.1: Design of slides for classroom interaction and e-learning
6. **T2.2.2: Development of practical assignments**
7. T2.2.3: Harmonisation of content
8. T2.2.4: Platform Architecture Specification and Design
9. T2.2.5: Platform Development
10. T2.2.6: Platform Optimisation

11. T2.3.1: Training of trainers
12. T2.3.2: Trainings at partner universities and companies
13. T2.3.3: Open education sessions
14. T2.3.4: Testing by students and practitioners at intensive courses
15. T2.3.5: Revision of content
16. T2.3.6: Accreditation and formalisation

The present document concerns the implementation of Task 2.2.2, in which practical assignments should be developed. The practical assignments will be developed, using as basis the syllabi that was designed within the objectives of Task 2.1.4 – *Design and planning of syllabi*, and will accompany the slides which were implemented during the Task 2.2.1 – *Design of slides for classroom interaction and e-learning*. Furthermore, the practical assignments will include identification of software tools.

2. DIGITAL WATER CURRICULUM

2.1. INTRODUCTION

A syllabus with its content for the subjects (i) IoT & Big Data and (ii) Cybersecurity in Critical Water infrastructure, was developed within the framework of Task 2.1.4 – *Design and planning of syllabi*. The syllabus was designed for two courses i) IoT and ii) Big Data applications in the water sector, which both incorporate cybersecurity topics.

The content of the courses was the basis for the implementation of the practical assignments, which will be part of the slides implemented in Task 2.2.1.

A brief description of the syllabi for the two courses, is presented in the following paragraphs.

2.2. 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 the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from ordinary household objects to sophisticated industrial tools[2].

The course enables students to understand the basics of IoT, and introduces some of the fields where the IoT can be applied, focusing in the application in the water industry.

The course is comprised by seven lectures as follows:

Table 1: Content of the "Internet of Things" course and responsible partner

	Lecture	Responsible partner
1.1	**Introduction to IoT**	UCY
1.2	**Sensors in IoT**	DOSCON
1.3	**Instrumentation and SCADA**	SmarTech
1.4	**Cybersecurity in IoT**	UGAL
1.5	**Standards & Good practices (including legal framework)**	NMBU
1.6	**Case studies based on simulations**	SumAqua
1.7	**Future trends in IoT**	NMBU

The detailed content of each of the course's lecture was developed by the responsible project partners, as it is shown in the above Table, and it can be found in the project's deliverables [*R2.1.4 Design and planning of syllabi*].

[2] https://www.oracle.com/in/internet-of-things/what-is-iot/ [Access: 13/12/2022]

2.3. BIG DATA APPLICATIONS IN THE WATER SECTOR

Big Data refers to data sets that are too large or complex to be dealt with by traditional data-processing application software[3].

The course aims to introduce the fundamentals of Big Data to the students and present the various applications within the context of the water industry.

The course is comprised by eight lectures as follows:

Table 2: Content of the "Big Data" course and responsible partner

	Lecture	Responsible partner
2.1	**Introduction to Big Data**	KU Leuven
2.2	**Big data analytics (including Artificial Intelligence and Machine Learning tools)**	UCY
2.3	**Visualization of data**	DOSCON
2.4	**Cybersecurity in Critical Water infrastructure**	NMBU
2.5	**Data safety and standardization (including crash course on open data)**	DOSCON
2.6	**Case studies**	SumAqua
2.7	**Data assessment exercises**	TH OWL
2.8	**Future trends of big data applications in the water sector**	NMBU

The detailed content of each of the course's lecture was developed by the responsible partner (see Table 2), and it can be found in the project's deliverables [*R2.1.4 Design and planning of syllabi*].

[3] Breur, Tom (July 2016). "Statistical Power Analysis and the contemporary "crisis" in social sciences". Journal of Marketing Analytics. London, England: Palgrave Macmillan. 4 (2–3): 61–65. doi:10.1057/s41270-016-0001-3. ISSN 2050-3318.

3. PRACTICAL ASSIGNMENTS

3.1. INTRODUCTION

For implementing the practical assignments for each of the lecture of the two courses, a template was prepared and distributed among the responsible partners. The template, which was in tabular form, is shown in the following Table. As it can be seen, the template consists of various information regarding the practical assignments, such as the type, the duration, the equipment/software to be used and related references.

The partners that prepared the content (see Tables 1 and 2) for the two courses (IoT and Big Data), were responsible for filling the template for the practical assignments of their assigned lecture.

It is noted that practical assignments were not developed for the lecture "1.6: Case studies based on simulations" of the IoT course, as well as for the lecture "2.6: Case studies" on the Biga Data course, since it was considered not necessary.

Table 3: Practical assignments template

Course Title
Topic Title
Title of Practical Assignment
Type of Assignment (Individual/Group)
Description/Question at stake
Software/Applications to be used
Equipment to be used
Duration/Deadline of Submission
Type of Deliverable (i.e., Essay/device/sensor/application/system/etc
Other specifications for the requested deliverable (i.e., no. of words, essay structure, programming language, etc.)
Related/Helpful References
Expected Outcome

The description of each practical assignment for each course is presented below.

The templates as filled in by the responsible partner is presented in Annex I.

3.2. INTERNET OF THINGS (IOT)

The practical assignments as prepared by the responsible partner for the "Internet of Things" course, are described below.

3.2.1 Introduction to IoT

The "Introduction to IoT" lecture duration will be 3 hours and will include three individual practical assignments. The students will have 20 minutes to choose and answer one of the following topics:

➔ **A**

- What are the key technologies driving the development of IoT? Can you give two real-life applications of each?
- List the components of an IoT ecosystem and explain them briefly.
- How do we define IoT protocols and what are their types? Give a brief explanation in an example for each IoT protocol.

➔ **B**

- How do M2M applications work? Give two examples of this type of application (Hint: An example is shown in the slides).
- What IoT architecture layers does the lecture propose and what are the basic IoT architecture layers? Give a brief description of the proposed layers of the IoT architecture.
- What is the role of IoT and WoT according to the lecture? How are these two connected and what examples are used to represent them?

➔ **C**

- Explain briefly (according to the lecture) the layers of the WoT architecture. Based on the WoT application example give 2 examples of your own.
- Based on the 4 examples "Why use IoT in industry", give two examples of IoT in industry. One of the examples should be based on the water industry.

3.2.2 Sensors in IoT

The "Sensors in IoT" lecture will have a duration of 2 hours and will include one practical assignment. The topic of the assignment is to **Write a report describing a system to read data from online sensors**.

The report must be the result of a group work, it is recommended to be comprised by 2000 – 3000 words and has to be delivered within 1 week.

The practical assignment has to involve the description of a principle of a water quality sensor, and of a system that can read water quality parameters from an online hardware, using MS word or Latex.

A list of useful references that can be used for the implementation of the assignment are the following:

- Review of sensors to monitor water quality: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC85442/lbna26325enn.pdf

- Smart Sensors for Real-Time Water Quality Monitoring: https://link.springer.com/book/10.1007/978-3-642-37006-9
- Ratnaweera, H.; Fettig, J. State of the Art of Online Monitoring and Control of the Coagulation Process. Water 2015, 7, 6574-6597: https://doi.org/10.3390/w7116574
- Communication protocols for wireless sensor networks: https://www.sciencedirect.com/science/article/pii/S2405844018340192
- Sensor Network Protocols (Mahgoub, I., & Ilyas, M. (2006). Sensor Network Protocols (1st ed.). CRC Press: https://doi.org/10.1201/9781420006346
- R A Atmoko, R Riantini and M K Hasin 2017 IoT real time data acquisition using MQTT protocol. J. Phys
- M. B. Yassein, M. Q. Shatnawi, S. Aljwarneh and R. Al-Hatmi, "Internet of Things: Survey and open issues of MQTT protocol," 2017 International Conference on Engineering & MIS (ICEMIS), 2017, pp. 1-6, doi: https://doi.org/10.1109/ICEMIS.2017.8273112
- V.Lakshmikantha, A.Hiriyannagowda, A.Manjunath, A. Patted, J. Basavaiah, A. Anthony, IoT based smart water quality monitoring system, 2021, Global Transitions Proceedings, vol .2 (2), pp 181-186: https://doi.org/10.1016/j.gltp.2021.08.062
- N. A. Cloete, R. Malekian and L. Nair, "Design of Smart Sensors for Real-Time Water Quality Monitoring," in IEEE Access, vol. 4, pp. 3975-3990, 2016, doi: https://doi.org/10.1109/ACCESS.2016.2592958

The expected outcome from this assignment is to be able to understand the principles and the features of a water quality IoT sensor, to learn different ways of data extraction from an online sensor and how to send data to a cloud.

3.2.3 Instrumentation and SCADA

The duration of the “Instrumentation and SCADA” lecture is 4 hours and consists of three individual practical assignments, each one has a submission deadline in three weeks. The students will have to submit the following assignments:

A. Design a control system and create a PLC application for control and data transmission for a water drilling system or a wastewater pumping system

Students will choose the automation equipment - PLC, I/O modules, communication modules, operating interfaces that fulfill the functionalities required for the system to be developed. An Integrated Architecture Builder (IAB) software application, which provides a graphic interface for this type of design of control and actuation systems, shall be used. Then, based on the functionality requirements, an application for the PLC will be implemented.

A Connected Components Workbench software (CCW), will be used for the PLC configuring, and an Integrated Architecture Builder (IAB) will be used for the design of the control system. A CCW software provides controller programming and simulation, device configuration and visualization with Human Machine Interface (HMI) editor[4]. A desktop/laptop in which IAB and CCW applications are installed, is necessary for implementing this assignment. In addition, a ladder diagram programming, according to the IEC 61131-part 3 standard, should be used.

Students must deliver a control system consisting of an architecture and a list of the equipment, and a software application.

The expected outcome from this assignment is that students will learn how to analyze the requirements for an automation application, how to design a PLC automation system and how to develop a PLC application.

B. Create an HMI application for the operator surface for a simple raw water drilling system or a wastewater pumping system

Following the system designed in Practical Assignment A, students should implement an operator interface application.

A Connected Components Workbench software (CCW) should be used, and a desktop/laptop in which a CCW application is installed, is necessary for implementing this assignment.

The expected outcome from this assignment is a software application, while students will learn to analyze the requirements for an HMI type application, to design a visualization application, and to develop an HMI application.

C. Create a SCADA application using Ignition

The third practical assignment of the lecture is the creation of a SCADA application using Ignition software. Students will have to configure and develop a SCADA application in Ignition v8.1.24 which will consist of a number of screens that will contain process graphics, tag values, trends, alarms, etc.

For the implementation of the assignment, a desktop/laptop in which the Ignition software will be installed, is necessary.

The expected outcome is a software application and students will learn to analyze the requirements for a SCADA type application and to design and develop a SCADA application.

[4] https://www.rockwellautomation.com/

A list of useful references that can be used for the implementation of the above assignments are listed below:

- Stuart G. McCrady, "Designing SCADA - Application Software - A Practical Approach", Elsevier, 2013
- Ronald L. Krutz, "Securing SCADA Systems", Wiley Publishing, Inc., 2006
- www.ab.com
- https://www.rockwellautomation.com/en-us/capabilities/industrial-automation-control/design-and-configuration-software.html
- https://www.rockwellautomation.com/en-us/support/product/product-selection-configuration/integrated-architecture-builder.html,
- https://inductiveautomation.com/ignition/platform

3.2.4 Cybersecurity in IoT

The fourth lecture of the "Internet of Things" course, is "Cybersecurity in IoT" and includes one practical assignment. The objective of the assignment is to **Write an essay for one of the common cyber threats**. The essay is individual and has to be submitted within 1 week.

The expected outcome from the essay is to highlight the importance of the cyber threat awareness within the context of securing the IoT devices. IoT devices collect and distribute more and more sensitive and informational data, mostly unencrypted, over the network, exposing them to the risk of being destroyed, altered or stolen. Knowing the most common cyber threats, understanding their impact and being aware of the major risks are important to prioritize efforts to secure IoT devices and data, allowing to reduce their exposure to cyberattacks. Students will increase their knowledge and readiness to prevent, reduce and defend against cyber threats.

The following useful references are provided:

- https://www.paloaltonetworks.com/cyberpedia/what-is-iot-security
- https://docs.paloaltonetworks.com/content/dam/techdocs/en_US/pdf/iot/iot-security-admin/iot-security-admin.pdf
- https://www.paloaltonetworks.com/resources/infographics/the-8-stages-of-the-iot-attack-lifecycle
- https://www.paloaltonetworks.com/resources/infographics/4-steps-to-reducing-iot-ot-security-threats-in-the-enterprise
- https://skillsforall.com/course/cybersecurity-essentials?userLang=en-US
- https://skillsforall.com/course/introduction-to-cybersecurity?userLang=en-US

- https://www.enisa.europa.eu/topics/cyber-threats/threats-and-trends

3.2.5 Standards & Good practices (including legal framework)

The practical assignment for the "Standards & Good practices" lecture is to **Write an essay on IoT security best practices**.

The essay can be either individual or in small groups, it is recommended to be comprised by 2500 – 3000 words and has to be delivered within 1 week.

The following links are provided and considered to be useful for the implementation of the essay:

- https://nordiciot.dk/ieee-and-iso-standards-for-iot/
- https://www.tandfonline.com/doi/full/10.1080/13600869.2022.2060468)
- https://www.enisa.europa.eu/publications/good-practices-for-security-of-iot-1
- https://www.enisa.europa.eu/publications/good-practices-for-security-of-iot
- https://standards.ieee.org/wp-content/uploads/import/documents/other/whitepaper-internet-of-things-2017-dh-v1.pdf
- https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/inspired/iot-regulations
- https://bgnetworks.com/the-state-of-iot-cyber-security/

3.2.6 Future trends in IoT

The assignment for this lecture is to **Write an essay on the future trends of IoT and provide an overview of the top 5 trends in 2023**.

The Internet of Things is expected to be characterized by continued growth, technological advancements, and increased integration into various industries, resulting in improved productivity, efficiency, and convenience. Being aware of the future trends in IoT can help individuals and organizations stay ahead of the curve, make informed decisions, and take advantage of new opportunities.

The essay must have at least 2500 words, it can be either individual or group, and the submittal deadline is 1 week.

A list of useful references that can be used for the implementation of the essay are the following:

- https://www.mdpi.com/2079-9292/10/19/2377/htm
- https://www.mdpi.com/2624-831X/3/1/9

- https://www.researchgate.net/profile/FaheemMasoodi/publication/348448892_Current_Trends_and_Future_Scope_for_the_Internet_of_Things/links/6015789145851517ef275d22/Current-Trends-and-Future-Scope-for-the-Internet-of-Things.pdf
- https://techreviewer.co/blog/top-iot-trends-in-2022-the-future-of-iot
- https://www.spiceworks.com/tech/iot/articles/what-is-internet-of-things/
- https://www.ubuntupit.com/emerging-iot-trends/
- https://www.iotforall.com/future-of-iot-technology-8-trends-for-businesses-to-watch-in-2022
- https://internetofbusiness.com/major-iot-trends-to-expect-in-2022/
- https://financesonline.com/iot-trends/

3.3. Big Data Applications in the Water Industry

The practical assignments as prepared by the responsible partner for the "Big Data Applications in the Water Industry" course, are described below.

3.3.1 Introduction to Big Data

The duration of the "Introduction to Big Data" lecture is 2 hours and the topic of the practical assignment is to **Explore and modeling a water quality dataset**. The assignment is individual and the duration for the completion is two weeks with a target set to 2 - 4 hours.

The objective of the assignment is to explore a dataset on water quality originating from a non-official online source (https://www.kaggle.com/datasets/adityakadiwal/water-potability). More specifically, an exploratory data analysis (data types, variable distributions, correlations, missing data, etc.) in which a simple toy model of the student's choice will be applied to the dataset aiming to predict the potability of a water body based on the provided water quality variables. A reflection on the model's application potential and on the trustworthiness of the dataset conclude the exercise. All steps of the process will be summarized in a written report with a clear narrative supplemented with graphs and code excerpts.

The software to be used is at the student's discretion, however a spreadsheet application is sufficient.

A list of useful references that can be used for the implementation of the assignment are the following:

- Kapelan, Z., Weisbord, E., Babovic, V. (2020). Digital Water: Artificial Intelligence Solutions for the Water Sector, IWA
- The Application of Artificial Intelligence in Hydrology, special issue of Water (ISSN 2073-4441), edited by G. Astray
- Machine Learning Algorithms for Hydraulic Engineering, special issue of Applied Sciences (ISSN 2076-3417), edited by F. Granata & R. Gargano

- Hall, M. A., Frank, E., & Witten, I. H. (2011). Data mining: practical machine learning tools and techniques. Morgan Kaufmann
- Kadiwal, A. (2020). Water Quality: Drinking water potability, public dataset on Kaggle
- Scikit-learn: Machine Learning in Python, Pedregosa et al., JMLR 12, pp. 2825-2830, 2011

After the completion of the assignment, students will learn how to perform an exploratory data analysis, how to fit a preliminary model into the dataset and will obtain additional software skills.

3.3.2 Big Data analytics (including Artificial Intelligence and Machine Learning tools)

"Big Data analytics" lecture's duration will be 3 hours, and includes two practical assignments. One of the assignments is individual, while the other assignment is in student's groups.

The topic of the individual assignment is the **Introduction to Data Analysis**. Students will deliver a set of Jupyter Notebooks, which will be implemented using a Python programming language.

The topic of the group project is the **Data Analytics and Visualization**. The group of students will deliver a set of Jupyter Notebooks using a Python programming language.

The following references can be used for implementing the assignments:

- D. Toomey, Learning Jupyter 5: Explore interactive computing using Python, Java, JavaScript, R, Julia, and JupyterLab, 2nd Edition, Packt Publishing, 2018.
- W. McKinney, Python for Data Analysis, 3rd Edition, O'Reilly, 2011.
- A. Galea, Beginning Data Science with Python and Jupyter: Use powerful tools to unlock actionable insights from data, Packt Publishing, 2018.

3.3.3 Visualization of data

"Visualization of data" is the third lecture of the course, and its duration is 2 hours. Students should **Design an optimal dashboard layout to visualize data from a small-scale treatment plant**.

The assignment will be implemented in small groups within 1 week.

During the process of implementing the group project, students should have in mind how an online sensor data shown in web widgets can be arranged in order to create a comprehensive representation of data from online sensors installed in a wastewater treatment plant. A fundamental understanding of norms and standards is necessary to create an easy-to-understand dashboard layout of online sensor data.

A web browser/Grafana or Thingsboard is essential for completing the assignment.

References that can be useful are listed below:

- S. M. Ali, N. Gupta, G. K. Nayak and R. K. Lenka, "Big data visualization: Tools and challenges," 2016 2nd International Conference on Contemporary Computing and Informatics (IC3I), 2016, pp. 656-660, doi: 10.1109/IC3I.2016.7918044
- Manuela Aparicio and Carlos J. Costa. 2015. Data visualization. Commun. Des. Q. Rev 3, 1 (November 2014), 7–11, https://doi.org/10.1145/2721882.2721883
- Antonis Protopsaltis, Panagiotis Sarigiannidis, Dimitrios Margounakis, and Anastasios Lytos. 2020. Data visualization in internet of things: tools, methodologies, and challenges. In Proceedings of the 15th International Conference on Availability, Reliability and Security (ARES '20). Association for Computing Machinery, New York, NY, USA, Article 110, 1–11. https://doi.org/10.1145/3407023.3409228
- Rajeev Agrawal, Anirudh Kadadi, Xiangfeng Dai, and Frederic Andres. 2015. Challenges and opportunities with big data visualization. In Proceedings of the 7th International Conference on Management of computational and collective intElligence in Digital EcoSystems (MEDES '15). Association for Computing Machinery, New York, NY, USA, 169–173. https://doi.org/10.1145/2857218.2857256, 5
- Ma D, Fan X, Gausemeier J, Grafe M, Virtual Reality & Augmented Reality in Industry, 2011, SpringerLink, Berlin, 978-3-642-17376-9
- Mirauda, D.; Capece, N.; Erra, U. Sustainable Water Management: Virtual Reality Training for Open-Channel Flow Monitoring. Sustainability 2020, 12, 757. https://doi.org/10.3390/su12030757
- M. Chaudhry, "Creating Effective Virtual Reality Learning Experiences: Lessons Learned," in Education and Training in Optics & Photonics Conference 2021, A. Danner, A. Poulin-Girard, and N. Wong, eds., OSA Technical Digest (Optica Publishing Group, 2021), paper Th4A.1
- Capece, N., Erra U.: StreamFlowVR: a tool for learning methodologies and measurement instruments for river flow through virtual reality. In: De Paolis (ed.) 6th International Conference AVR 2019, LNCS 11614. Springer, Italy (2019)

3.3.4 Cybersecurity in Critical Water infrastructure

The fourth lecture of the course is “Cybersecurity in Critical Water Infrastructure”. Students either individually or in small groups will have to **Write an essay about one of the cybersecurity incidents in the water sector**.

The critical water infrastructure has been affected by constant digital growth, and the ongoing digital evolution/transformation brings efficiency and monitoring advantages. However, it also exposes water infrastructure to new threats, including cyberattacks. Thus, analysing a cybersecurity incident is vital for understanding adversarial behaviour (the methods, tools, and tactics used by attackers),

developing mitigation strategies to prevent or minimize similar attacks, and identifying trends and patterns.

The essay should be delivered within 1 week, and must be comprised by 2500 – 3000 words.

The following links are provided and considered to be useful for the implementation of the essay:

- Industrial Network Security: https://www.sciencedirect.com/book/9780124201149/industrial-network-security
- Guide to Industrial Control Systems (ICS) Security: https://nvlpubs.nist.gov/nistpubs/specialpublications/nist.sp.800-82r2.pdf
- Cyber Security for Cyber Physical Systems: https://link.springer.com/content/pdf/10.1007/978-3-319-75880-0.pdf)
- Cyber Security for the Water Sector: https://wcwc.ca/cyber-security-for-the-water-sector/
- Infrastructure Cybersecurity/Water systems: https://www.rpc.senate.gov/policy-papers/infrastructure-cybersecurity-water-systems
- A Review of Cybersecurity Incidents in the Water Sector: https://arxiv.org/pdf/2001.11144.pdf

3.3.5 Data safety and standardization (including crash course on open data)

Within the context of the "Data safety and standardization" lecture, the students, in groups, should **Gather and combine data from different sources**. The assignment should be delivered within 1 week.

Today's environment requires handling of large amounts of data. Data can be sensitive or valuable but need to be collected and processed in order to be used. Knowing how to handle and process data correctly is becoming more important. This assignment aims to inform students about aspects of data handling when it comes to data safety and data standards.

The software that can be used for the assignment is Python and Excel, while the following links could be useful:

- Data security threats: https://www.sciencedirect.com/science/article/pii/S2214785322018855
- Data security regulations: https://gdpr-info.eu/, https://oag.ca.gov/privacy/ccpa and https://www.hhs.gov/hipaa
- Data Security planning frameworks: https://www.nist.gov/cyberframework and https://www.iso.org/obp/ui/#iso:std:iso-iec:27000:ed-5:v1:en

3.3.6 Data assessment exercises

During the "Data assessment exercise" lecture, the students, individually or in small groups, will have to **Self-learn an application of a programming language**.

Students should develop a water-related application using "R" as a programming language within 2 weeks. Water level data which are available for public and are of good quality, can be used for the implementation of the assignment. The expected outcome is to predict water levels with the use of a programming code for the calculations.

The following relevant references can be used:

- J. Warren, N. Marz, Big Data, Manning Publications 2015, E. Curry et al., The Elements of Big Data Value, Springer 2021; J. Grus
- Data Science from Scratch, O'Reilly 2019; https://www.pegelonline.wsv.de

3.3.7 Future trends of Big Data applications in the water sector

The assignment for this lecture is to **Write an essay on the future trends of Big Data applications in the water sector and provide an overview of the top 3 trends of 2023**.

Big Data applications in the water sector use large and complex datasets from various sources (e.g., sensors, drones, and simulations) to improve decision-making and water management and minimize water leakage. Understanding the future trends of Big Data applications in the water sector can bring significant benefits in terms of improved water management, enhanced monitoring and prediction, increased efficiency, better decision-making, improved water quality monitoring, and optimized water resource planning.

The essay must have at least 2500 words, it can be either individual or group, and the submittal deadline is 1 week.

A list of useful references that can be used for the implementation of the essay are the following:

- Top trends in Big Data for 2022 and beyond: https://www.techtarget.com/searchdatamanagement/feature/Top-trends-in-big-data-for-2021-and-beyond
- On Big Data, artificial intelligence, and smart cities: https://www.sciencedirect.com/science/article/abs/pii/S0264275118315968
- How can Big Data and machine learning benefit environment and water management: a survey of methods, applications, and future directions: https://iopscience.iop.org/article/10.1088/1748-9326/ab1b7d
- Popular Big Data Technologies In 2022: https://www.jigsawacademy.com/blog/data-science/popular-big-data-technologies-in-2022/
- Role of Big Data analytics in solving water problems: https://medium.com/@mynab247/role-of-big-data-analytics-in-solving-water-problems-728ccad41d78

- Big Data in the water industry: How does it provide big value?: https://www.crayondata.com/big-data-in-the-water-industry-how-does-it-provide-big value/#:~:text=The%20Benefits%20That%20Big%20Data%20Can%20Offer%20the%20Water%20Industry&text=Predictive%20maintenance%20strategies%20can%20leverage,costly%20downtime%20or%20machine%20failure
- Big Data analysis for studying water supply and sanitation coverage in cities (Russia) https://www.revistaespacios.com/a19v40n27/a19v40n27p21.pdf
- Harnessing the Fourth Industrial Revolution for water https://www.weforum.org/reports/harnessing-the-fourth-industrial-revolution-for-water/
- An overview of Big Data applications in water resources engineering: https://www.researchgate.net/publication/334710343_An_Overview_of_Big_Data_Applications in_Water_Resources_Engineering
- Security and privacy for Big Data: https://www.routledge.com/Trust-Security-and-Privacy-for-Big-Data/Alazab-Gupta/p/book/9781032047508#

4. CONCLUSIONS/NEXT STEPS

The objective of the present document was to report upon the implementation of Task 2.2.2 “Practical Assignments”, which is part of the Work Package 2 “Digital Water Curriculum”.

For implementing Task 2.2.2, a template was distributed among the responsible partners. The template, which was in tabular form, consists of various information in regards to the practical assignments, such as the type, the grading, the duration, the equipment/software to be used and related references. The templates as filled in by the responsible partner is presented in Annex I.

The practical assignments were developed using as basis the syllabi that was designed within the objectives of Task 2.1.4 – Design and planning of syllabi, and will accompany the slides which were implemented during the Task 2.2.1 – Design of slides for classroom interaction and e-learning.

The overall contribution of the practical assignments to the courses’ grading is 35%.

The outcomes of the present Task, will be harmonised by the course editors within the objectives of the Task 2.2.3 – Harmonisation of content.

5. ANNEX

Annex I: Practical assignments

INTERNET OF THINGS

➔ Introduction to IoT [UCY]

Course Title	Internet of Things
Topic Title	1.1 Introduction to IoT
Title of Practical Assignment	**A.** What are the key technologies driving the development of IoT? Can you give 2 real-life applications of each? **B.** List the components of an IoT ecosystem and explain them briefly. **C.** What is the role of IoT and WoT according to the lecture? How are these 2 connected and what example is used to represent them?
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	
Software/Applications to be used	
Equipment to be used	
Duration/Deadline of Submission	20 minutes
Type of Deliverable (i.e. Essay/device/sensor/application/system/etc	
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	
References Provided	Lecture's powerpoint

Course Title	Internet of Things
Topic Title	1.1 Introduction to IoT
Title of Practical Assignment	**A.** How do we define IoT protocols and what are their types? Give a brief explanation in an example for each IoT protocol. **B.** How do M2M applications work? Give 2 examples of this type of application (Hint: An example is shown in the slides). **C.** What IoT architecture layers does the lecture propose and what are the basic IoT architecture layers? Give a brief description of the proposed layers of the IoT architecture.
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	
Software/Applications to be used	
Equipment to be used	
Duration/Deadline of Submission	20 minutes
Type of Deliverable (i.e. Essay/device/sensor/application/system/etc	
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	
References Provided	Lecture's powerpoint

Course Title	Internet of Things
Topic Title	1.1 Introduction to IoT
Title of Practical Assignment	**A.** Explain briefly (according to the lecture) the layers of the WoT architecture. Based on the WoT application example give 2 examples of your own. **B.** Based on the 4 examples "**Why use IoT in industry**", give 2 examples of IoT in industry. **One of the examples should be based on the water industry**.
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	
Software/Applications to be used	
Equipment to be used	
Duration/Deadline of Submission	20 minutes
Type of Deliverable (i.e. Essay/device/sensor/application/system/etc	
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	
References Provided	Lecture's powerpoint

➔ Sensors in IoT [DOSCON]

Course Title	Internet of Things (IoT)
Topic Title	1.2 Sensors in IoT
Title of Practical Assignment	A. Write a report discribing a system to read data from online sensors
Type of Assignment (Individual/Group)	Group
Grading and % contribution to overall Course Grade	30
Description/Question at stake	Online sensors are an integral part of the water and wastewater infrastructure. Water-quality parameters measured by these online sensors in the form of digital signals should be processed before sending them to the cloud. This task involves discribing a. working principle of a water quality sensor (pH, conductivity, turbidity, orp) b. a system that can read water quality parameters from online hardware and send it to a cloud
Software/Applications to be used	MS word or Latex
Equipment to be used	A laptop/PC connected to internet
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	A report discribing a system to read data from online sensors and send data to a cloud
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	2000-3000
Related/Useful References	•Review of sensors to monitor water quality https://publications.jrc.ec.europa.eu/repository/bitstream/JRC85442/lbna26325enn.pdf •Smart Sensors for Real-Time Water Quality Monitoring (https://link.springer.com/book/10.1007/978-3-642-37006-9) •Ratnaweera, H.; Fettig, J. State of the Art of Online Monitoring and Control of the Coagulation Process. Water 2015, 7, 6574-6597. https://doi.org/10.3390/w7116574 •Communication protocols for wireless sensor networks (https://www.sciencedirect.com/science/article/pii/S2405844018340192) •Sensor Network Protocols (Mahgoub, I., & Ilyas, M. (2006). Sensor Network Protocols (1st ed.). CRC Press. https://doi.org/10.1201/9781420006346 •R A Atmoko, R Riantini and M K Hasin 2017 IoT real time data acquisition using MQTT protocol. J. Phys. •M. B. Yassein, M. Q. Shatnawi, S. Aljwarneh and R. Al-Hatmi, "Internet of Things: Survey and open issues of MQTT protocol," 2017 International Conference on Engineering & MIS (ICEMIS), 2017, pp. 1-6, doi: https://doi.org/10.1109/ICEMIS.2017.8273112. •V.Lakshmikantha, A.Hiriyannagowda, A.Manjunath, A. Patted, J. Basavaiah, A. Anthony, IoT based smart water quality monitoring system, 2021, Global Transitions Proceedings, vol .2 (2), pp 181-186. https://doi.org/10.1016/j.gltp.2021.08.062 •N. A. Cloete, R. Malekian and L. Nair, "Design of Smart Sensors for Real-Time Water Quality Monitoring," in IEEE Access, vol. 4, pp. 3975-3990, 2016, doi: https://doi.org/10.1109/ACCESS.2016.2592958
Expected Outcome	Understand the working principle and the features of Water quality IoT sensor Different ways of extracting data from online sensor Learn how to send data to a cloud

➔ Instrumentation and SCADA [SmarTech]

Course Title	Internet of Things (IoT)
Topic Title	1.3 Instrumentation & SCADA
Title of Practical Assignment	A. Design a control sistem and create a PLC application for control and data transmission for a water drilling system or a wastewater pumping system
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	Students will choose the automation equipment - PLC, I/O modules, communication modules, operating interfaces that fulfill the functionalities required for the system to be developed. For this task we will use - Integrated Architecture Builder (IAB) - a software application that provides a graphic interface for this type of design of control and actuation systems. Then, based on the functionality requirements, an application for the PLC will be configured.
Software/Applications to be used	Rockwell Automation Software - Connected Components Workbench - will be used for PLC configuring and programing and Integrated Architecture Builder (IAB) - for design the control sistem.
Equipment to be used	Computer or laptop with IAB and CCW applications installed.
Duration/Deadline of Submission	3 weeks
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	A project of a control system consisting of an architecture and a list of equipment that fulfills the required functionalities and a software application will result from this practical assignement.
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	Ladder diagram programming according to the IEC 61131 part 3 standard will be used.
Related/Useful References	1. Stuart G. McCrady, "Designing SCADA - Application Software - A Practical Approach", Elsevier, 2013, 2. Ronald L. Krutz, "Securing SCADA Systems", Wiley Publishing, Inc., 2006, 3. www.ab.com, 4.https://www.rockwellautomation.com/en-us/capabilities/industrial-automation-control/design-and-configuration-software.html 5.https://www.rockwellautomation.com/en-us/support/product/product-selection-configuration/integrated-architecture-builder.html, 6.https://inductiveautomation.com/ignition/platform
Expected Outcome	Students will learn to analyze the requirements for an automation application, they will learn to design a PLC automation system that can achieve the requirements of the application theme, they will learn to develop a PLC application that will provide the functionality required by the theme.

Course Title	Internet of Things (IoT)
Topic Title	1.3 Instrumentation & SCADA
Title of Practical Assignment	B. Create an HMI application for the operator interface for a simple raw water drilling system or a wastewater pumping system
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	Starting from the system designed in Practical assisment A , students will configure an operator interface application for the given system. The functionality required for this interface will be implemented.
Software/Applications to be used	Rockwell Automation Software - Connected Components Workbench - will be used.
Equipment to be used	Computer or laptop with CCW application installed.
Duration/Deadline of Submission	3 weeks
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	A software application will result from this practical assignement.
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	The functionalities of the CCW application for drawing screens, creating tags and displaying them on the screens will be used.
Related/Useful References	1. Stuart G. McCrady, "Designing SCADA - Application Software - A Practical Approach", Elsevier, 2013, 2. Ronald L. Krutz, "Securing SCADA Systems", Wiley Publishing, Inc., 2006, 3. www.ab.com, 4.https://www.rockwellautomation.com/en-us/capabilities/industrial-automation-control/design-and-configuration-software.html 5.https://www.rockwellautomation.com/en-us/support/product/product-selection-configuration/integrated-architecture-builder.html, 6.https://inductiveautomation.com/ignition/platform
Expected Outcome	Students will learn to analyze the requirements for an HMI type application, they will learn to design the visualization application according to the given theme, they will learn to develop an HMI application that will provide the functionalities required by the theme.

Course Title	Internet of Things (IoT)
Topic Title	1.3 Instrumentation & SCADA
Title of Practical Assignment	C. Create a SCADA application using Ignition
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	Students will configure and develop a SCADA application in Ignition v8.1.24 consisting of a number of screens that will contain process graphics, tag values, trends, alarms, etc.
Software/Applications to be used	Inductive Ignition software will be used.
Equipment to be used	Computer or laptop with Ignition application installed.
Duration/Deadline of Submission	3 weeks
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	A software application will result from this practical assignement.
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	The functionalities of the Ignition IDE application for drawing screens, creating tags and displaying them on the screens will be used.
Related/Useful References	1. Stuart G. McCrady, "Designing SCADA - Application Software - A Practical Approach", Elsevier, 2013, 2. Ronald L. Krutz, "Securing SCADA Systems", Wiley Publishing, Inc., 2006, 3. www.ab.com, 4.https://www.rockwellautomation.com/en-us/capabilities/industrial-automation-control/design-and-configuration-software.html 5.https://www.rockwellautomation.com/en-us/support/product/product-selection-configuration/integrated-architecture-builder.html, 6.https://inductiveautomation.com/ignition/platform
Expected Outcome	Students will learn to analyze the requirements for a SCADA type application, they will learn to design the application, they will learn to develop a SCADA application that will provide the functionalities required by the theme.

➔ Cybersecurity in IoT [UGAL]

Course Title	Internet of Things (IoT)
Topic Title	1.4 Cybersecurity in IoT
Title of Practical Assignment	A. Write an essay for one of the common cyber threats
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	IoT devices collect and distribute more and more sensitive and informational data, mosltly unencrypted, over the network, exposing it to the risk of being destroyed, altered or stolen. Knowing the most common cyber threats, understanding their impact and being aware of the major risks are important to prioritize efforts to secure our devices and data, allowing to reduce their exposure to cyber attacks.
Software/Applications to be used	-
Equipment to be used	A computer connected to the Internet
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	Essay
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	State an opinion on the importance of the cyber threat awareness discussed in the context of securing IoT devices.
Related/Useful References	1. https://www.paloaltonetworks.com/cyberpedia/what-is-iot-security 2.https://docs.paloaltonetworks.com/content/dam/techdocs/en_US/pdf/iot/iot-security-admin/iot-security-admin.pdf 3.https://www.paloaltonetworks.com/resources/infographics/the-8-stages-of-the-iot-attack-lifecycle 4.https://www.paloaltonetworks.com/resources/infographics/4-steps-to-reducing-iot-ot-security-threats-in-the-enterprise 5.https://skillsforall.com/course/cybersecurity-essentials?userLang=en-US 6. https://skillsforall.com/course/introduction-to-cybersecurity?userLang=en-US 7. https://www.enisa.europa.eu/topics/cyber-threats/threats-and-trends
Expected Outcome	Increased knowledge and readiness to prevent, reduce and defend against cyber threats.

➔ Standards and Good Practices [NMBU]

Course Title	Internet of Things (IoT)
Topic Title	1.5 Standars & Good practices (incl. Legal framework)
Title of Practical Assignment	A. Write an essay on IoT security best practices
Type of Assignment (Individual/Group)	Individually or in small groups
Description/Question at stake	The IoT has the potential to transform various industries by enabling seamless communication and data exchange between devices, allowing for greater efficiency, automation, and improved decision-making. However, the security of the IoT is an increasing concern, and compromising IoT devices/networks would allow unauthorized access to customers' information and organizations' systems. It is, therefore, essential to analyze the relevant IoT security threats and accordingly discuss IoT security best practices to improve the security of devices, software, data, and networks within IoT environments.
Software/Applications to be used	
Equipment to be used	A laptop connected to the Internet
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	Essay
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	2500 - 3000 words
Related/Helpful References	1. https://nordiciot.dk/ieee-and-iso-standards-for-iot/, 2.https://www.tandfonline.com/doi/full/10.1080/13600869.2022.2060468), 3.https://www.enisa.europa.eu/publications/good-practices-for-security-of-iot-1 , 4.https://www.enisa.europa.eu/publications/good-practices-for-security-of-iot), 5.https://standards.ieee.org/wp-content/uploads/import/documents/other/whitepaper-internet-of-things-2017-dh-v1.pdf), https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/inspired/iot-regulations, https://bgnetworks.com/the-state-of-iot-cyber-security/
Expected Outcome	

➔ Future trends of IoT [NMBU]

Course Title	Internet of Things (IoT)
Topic Title	1.7 Future trends of IoT
Title of Practical Assignment	Write an essay on the future trends of IoT, and provide an overview of 5 top trends to look out for in 2023
Type of Assignment (Individual/Group)	Individually or in small groups
Description/Question at stake	The Internet of Things (IoT) is expected to be characterized by continued growth, technological advancements, and increased integration into various industries, resulting in improved productivity, efficiency, and convenience. Knowing future trends in IoT can help individuals and organizations stay ahead of the curve, make informed decisions, and take advantage of new opportunities.
Software/Applications to be used	
Equipment to be used	A laptop connected to the Internet
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	Essay
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	2500 - 3000 words
Related/Useful References	1.https://www.mdpi.com/2079-9292/10/19/2377/htm, https://www.mdpi.com/2624-831X/3/1/9, 2.https://www.researchgate.net/profile/Faheem-Masoodi/publication/348448892_Current_Trends_and_Future_Scope_for_the_Internet_of_Things/links/6015789145851517ef275d22/Current-Trends-and-Future-Scope-for-the-Internet-of-Things.pdf, 3.https://techreviewer.co/blog/top-iot-trends-in-2022-the-future-of-iot, 4.https://www.spiceworks.com/tech/iot/articles/what-is-internet-of-things/, 5.https://www.ubuntupit.com/emerging-iot-trends/, https://www.iotforall.com/future-of-iot-technology-8-trends-for-businesses-to-watch-in-2022, https://internetofbusiness.com/major-iot-trends-to-expect-in-2022/, https://financesonline.com/iot-trends/
Expected Outcome	

BIG DATA APPLICATIONS IN THE WATER INDUSTRY

➔ Introduction to Big Data [KU Leuven]

Course Title	Big Data applications in the water sector
Topic Title	1.1 Introduction to Big Data
Title of Practical Assignment	Exploring and modeling a water quality dataset
Type of Assignment (Individual/Group)	Individual
Description/Question at stake	The student explores a dataset on water quality originating from a non-official online source (https://www.kaggle.com/datasets/adityakadiwal/water-potability). The student starts with an exploratory data analysis (data types, variable distributions, correlations, missing data...). Herafter, (s)he tries to come up with a simple toy model using domain knowledge (e.g. reasonable values of pH values). This model is applied to the dataset in an attempt to predict the potability of a water body based on the provided water quality variables. Finally, a reflection on the model's application potential and on the trustworthiness of the dataset conclude the exercise. All steps of the process are summarized in a written report with a clear narrative supplemented with graphs and code exerpts.
Software/Applications to be used	At student's discretion, but given the simple nature of the required modeling, a spreasheet application suffices.
Equipment to be used	Dataset available online.
Duration/Deadline of Submission	2 weeks (target time spent: 2 - 4 hours)
Type of Deliverable (i.e. Essay/device/sensor/application/system/etc	Written report (description of approach with a focus on graphs and code excerpts)
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	Three main parts in report: 1) data exploration 2) data modeling 3) reflection
Related/Useful References	1.Kapelan, Z., Weisbord, E., Babovic, V. (2020). Digital Water: Artificial Intelligence Solutions for the Water Sector, IWA. 2.The Application of Artificial Intelligence in Hydrology, special issue of Water (ISSN 2073-4441), edited by G. Astray. 3.Machine Learning Algorithms for Hydraulic Engineering, special issue of Applied Sciences (ISSN 2076-3417), edited by F. Granata & R. Gargano. 4.Hall, M. A., Frank, E., & Witten, I. H. (2011). Data mining: practical machine learning tools and techniques. Morgan Kaufmann. 5.Kadiwal, A. (2020). Water Quality: Drinking water potability, public dataset on Kaggle. 6.Scikit-learn: Machine Learning in Python, Pedregosa et al., JMLR 12, pp. 2825-2830, 2011.
Expected Outcome	skills: 1) exploratory data analysis 2) preliminary model fitting 3) acquiring additional software skills

➔ Big Data analytics [UCY]

Course Title	Big Data Analytics
Topic Title	1.1 Big Data Analytics
Title of Practical Assignment	A. Introduction to Data Analysis
Type of Assignment (Individual/Group)	Individual
Grading and % contribution to overall Course Grade	40%
Description/Question at stake	
Software/Applications to be used	Python IDE, Jupyter Notebooks, Google Colab
Equipment to be used	
Duration/Deadline of Submission	3 hours
Type of Deliverable (i.e. Essay/device/sensor/application/system/etc	A Set of Jupyter Notebooks
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	Python Programming Language
References Provided	1. D. Toomey, Learning Jupyter 5: Explore interactive computing using Python, Java, JavaScript, R, Julia, and JupyterLab, 2nd Edition, Packt Publishing, 2018. 2. W. McKinney, Python for Data Analysis, 3rd Edition, O'Reilly, 2011. 3. A. Galea, Beginning Data Science with Python and Jupyter: Use powerful tools to unlock actionable insights from data, Packt Publishing, 2018.

Course Title	Big Data Analytics
Topic Title	1.1 Big Data Analytics
Title of Practical Assignment	B. Data Analytics and Visualisation
Type of Assignment (Individual/Group)	Group
Grading and % contribution to overall Course Grade	20%
Description/Question at stake	
Software/Applications to be used	Python IDE, Jupyter Notebooks, Google Colab
Equipment to be used	
Duration/Deadline of Submission	3 hours
Type of Deliverable (i.e. Essay/device/sensor/application/system/etc	A Set of Jupyter Notebooks
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	Python Programming Language
References Provided	1. D. Toomey, Learning Jupyter 5: Explore interactive computing using Python, Java, JavaScript, R, Julia, and JupyterLab, 2nd Edition, Packt Publishing, 2018. 2. W. McKinney, Python for Data Analysis, 3rd Edition, O'Reilly, 2011. 3. A. Galea, Beginning Data Science with Python and Jupyter: Use powerful tools to unlock actionable insights from data, Packt Publishing, 2018.

➔ Visualization of data [DOSCON]

Course Title	Big Data applications in the water sector
Topic Title	1.3 Visualization of data
Title of Practical Assignment	A. Design an optimal dashboard layout to vizualize data from a small-scale treatment plant
Type of Assignment (Individual/Group)	Group
Description/Question at stake	Real-time data from IoT devices can be visualized in various forms using web widgets. A fundamental understanding of norms and standards is necessary to create an easy-to-understand dashboard layout of online sensor data. How do we arrange online sensor data shown in web widgets to create a comprehensive representation of data from online sensors installed in a wastewater treatment plant?
Software/Applications to be used	web-browser/Grafana or Thingsboard
Equipment to be used	PC with a web browser
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	
Related/Useful References	1. S. M. Ali, N. Gupta, G. K. Nayak and R. K. Lenka, "Big data visualization: Tools and challenges," 2016 2nd International Conference on Contemporary Computing and Informatics (IC3I), 2016, pp. 656-660, doi: 10.1109/IC3I.2016.7918044. 2. Manuela Aparicio and Carlos J. Costa. 2015. Data visualization. Commun. Des. Q. Rev 3, 1 (November 2014), 7–11. https://doi.org/10.1145/2721882.2721883 3. Antonis Protopsaltis, Panagiotis Sarigiannidis, Dimitrios Margounakis, and Anastasios Lytos. 2020. Data visualization in internet of things: tools, methodologies, and challenges. In Proceedings of the 15th International Conference on Availability, Reliability and Security (ARES '20). Association for Computing Machinery, New York, NY, USA, Article 110, 1–11. https://doi.org/10.1145/3407023.3409228 4. Rajeev Agrawal, Anirudh Kadadi, Xiangfeng Dai, and Frederic Andres. 2015. Challenges and opportunities with big data visualization. In Proceedings of the 7th International Conference on Management of computational and collective intElligence in Digital EcoSystems (MEDES '15). Association for Computing Machinery, New York, NY, USA, 169–173. https://doi.org/10.1145/2857218.2857256, 5. Ma D, Fan X, Gausemeier J, Grafe M, Virtual Reality & Augmented Reality in Industry, 2011, SpringerLink, Berlin, 978-3-642-17376-9. 6. Mirauda, D.; Capece, N.; Erra, U. Sustainable Water Management: Virtual Reality Training for Open-Channel Flow Monitoring. Sustainability 2020, 12, 757. https://doi.org/10.3390/su12030757. 7. M. Chaudhry, "Creating Effective Virtual Reality Learning Experiences: Lessons Learned," in Education and Training in Optics & Photonics Conference 2021, A. Danner, A. Poulin-Girard, and N. Wong, eds., OSA Technical Digest (Optica Publishing Group, 2021), paper Th4A.1. 8. Capece, N., Erra U.: StreamFlowVR: a tool for learning methodologies and measurement instruments for river flow through virtual reality. In: De Paolis (ed.) 6th International Conference AVR 2019, LNCS 11614. Springer, Italy (2019)
Expected Outcome	

➔ Cybersecurity in Critical Water Infrastructure [NMBU]

Course Title	Big Data applications in the water sector
Topic Title	1.4 Cybersecurity in Critical Water Infrastructure
Title of Practical Assignment	A. Write an essay about one of the cybersecurity incidents in the water sector
Type of Assignment (Individual/Group)	Individually or in small groups
Description/Question at stake	The critical water infrastructure has been affected by constant digital growth, and the ongoing digital evolution/transformation brings efficiency and monitoring advantages. However, it also exposes water infrastructures to new threats, including cyberattacks. Thus, analysing a cybersecurity incident is vital for understanding adversarial behaviour (the methods, tools, and tactics used by attackers), developing mitigation strategies to prevent or minimize similar attacks, and identifying trends and patterns.
Software/Applications to be used	
Equipment to be used	A laptop connected to the Internet
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	Essay
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	2500 - 3000 words
Related/Useful References	1. Industrial Network Security https://www.sciencedirect.com/book/9780124201149/industrial-network-security 2. Guide to Industrial Control Systems (ICS) Security https://nvlpubs.nist.gov/nistpubs/specialpublications/nist.sp.800-82r2.pdf 3. Cyber Security for Cyber Physical Systems (https://link.springer.com/content/pdf/10.1007/978-3-319-75880-0.pdf) 4. Cyber Security for the Water Sector (https://wcwc.ca/cyber-security-for-the-water-sector/) 5. Infrastructure Cybersecurity: Water systems (https://www.rpc.senate.gov/policy-papers/infrastructure-cybersecurity-water-systems) 6. A Review of Cybersecurity Incidents in the Water Sector (https://arxiv.org/pdf/2001.11144.pdf)
Expected Outcome	

➔ Data safety and standardization [NMBU]

Course Title	Big Data applications in the water sector
Topic Title	1.5 Data safety and standardization incl. crash course on open data
Title of Practical Assignment	A. Gathering and combining data from different sources
Type of Assignment (Individual/Group)	Group
Description/Question at stake	Today's environment require handling of large amounts of data. Data can be sensitive or valuable but needs to be collected and processed to be used. Knowing how to handle and process data correctly is becoming more important. This course aims to inform students about aspects of data handling when it comes to data safety and data standards.
Software/Applications to be used	Python, Excel
Equipment to be used	PC with internet
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	
Related/Helpful References	1. Data security threats https://www.sciencedirect.com/science/article/pii/S2214785322018855 2. Data security regulations https://gdpr-info.eu/ https://oag.ca.gov/privacy/ccpa https://www.hhs.gov/hipaa 3. Data Security planning frameworks https://www.nist.gov/cyberframework https://www.iso.org/obp/ui/#iso:std:iso-iec:27000:ed-5:v1:en
Expected Outcome	

➔ Data assessment exercises [THOWL]

Course Title	Big Data applications in the water sector
Topic Title	1.7 Data assessment exercises
Title of Practical Assignment	A. Self-learning of an application of a programming language
Type of Assignment (Individual/Group)	Individual (or in small groups)
Description/Question at stake	Water level data are available as public data in good quality and data density. With simple scripts, hydrographs of the water gauges are shown, the discharge velocity of high and low water is determined. Furthermore, the dependence of the water level on precipitation in the surrounding area is determined.
Software/Applications to be used	Programming language R
Equipment to be used	PC
Duration/Deadline of Submission	2 weeks
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	data and programme code
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	Programme code and an explanatory elaboration on it.
Related/Useful References	J. Warren, N. Marz, Big Data, Manning Publications 2015, E. Curry et al., The Elements of Big Data Value, Springer 2021; J. Grus, Data Scrience from Scratch, O'Reilly 2019; https://www.pegelonline.wsv.de
Expected Outcome	Prediction of the water level, programme code for the calculation

➔ Future trends of Big Data applications in water sector [NMBU]

Course Title	Big Data applications in the water sector
Topic Title	1.8 Future trends of big data applications in the water sector
Title of Practical Assignment	Write an essay on the future trends of big data applications in the water sector, and provide an overview of 3 top trends for 2023
Type of Assignment (Individual/Group)	Individually or in small groups
Description/Question at stake	Big data applications in the water sector use large and complex datasets from various sources (e.g., sensors, drones, and simulations) to improve decision-making and water management and minimize water leakage. Understanding the future trends of big data applications in the water sector can bring significant benefits in terms of improved water management, enhanced monitoring and prediction, increased efficiency, better decision-making, improved water quality monitoring, and optimized water resource planning.
Software/Applications to be used	
Equipment to be used	A laptop connected to the Internet
Duration/Deadline of Submission	1 week
Type of Deliverable (i.e. Essay/device/sensor/application/system/...	Essay
Other specifications for the requested deliverable (i.e. no. of words, essay structure, programming language, etc)	2500 - 3000 words
Related/Useful References	1. Top trends in big data for 2022 and beyond (https://www.techtarget.com/searchdatamanagement/feature/Top-trends-in-big-data-for-2021-and-beyond) 2. On big data, artificial intelligence, and smart cities (https://www.sciencedirect.com/science/article/abs/pii/S0264275118315968) 3. How can bid data and machine learning benefit environment and water management: a survey of methods, applications, and future directions (https://iopscience.iop.org/article/10.1088/1748-9326/ab1b7d) 4. Popular Big Data Technologies in 2022 (https://www.jigsawacademy.com/blog/data-science/popular-big-data-technologies-in-2022/) 5. Role of big data analytics in solving water problems (https://medium.com/@mynab247/role-of-big-data-analytics-in-solving-water-problems-728ccad41d78) 6. Big data in the water industry: How does it provide big value? (https://www.crayondata.com/big-data-in-the-water-industry-how-does-it-provide-big-value/#:~:text=The%20Benefits%20That%20Big%20Data%20Can%20Offer%20the%20Water%20Industry&text=Predictive%20maintenance%20strategies%20can%20leverage,costly%20downtime%20or%20machine%20failure.) 7. Big data analysis for studying water supply and sanitation coverage in cities (Russia) (https://www.revistaespacios.com/a19v40n27/a19v40n27p21.pdf) 8. Harnessing the Fourth Industrial Revolution for water (https://www.weforum.org/reports/harnessing-the-fourth-industrial-revolution-for-water/) 9. An overview of bid data applications in water resources engineering (https://www.researchgate.net/publication/334710343_An_Overview_of_Big_Data_Applications_in_Water_Resources_Engineering) 10. Security and privacy for big data (https://www.routledge.com/Trust-Security-and-Privacy-for-Big-Data/Alazab-Gupta/p/book/9781032047508#)
Expected Outcome	