DIEM - University of Salerno
Master's degree in Computer Engineering
Situation Awareness

Report
Project 3: E-learning

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Chapter 1

Introduction

The objective of this project is to implement a comprehensive e-learning system designed to assist users in tailoring their learning pathways and enhancing their skill sets. Developed with a strong emphasis on situational awareness, this project is structured into two primary components: the first involves *Goal-Driven Task Analysis* (GDTA), and the second focuses on the implementation of an integrated dashboard.

This system is meticulously crafted with a **User-Centric Approach**, ensuring that users can effectively monitor their competencies and track their learning progress. In developing the GDTA, we delineated operational concepts through detailed personas and scenario analysis, ensuring that the system is attuned to the diverse needs and contexts of its users. To fulfill the goals described inside the GDTA, we implemented two dashboards: the first dashboard is focused on the user's global learning progress, while the second dashboard is focused on the user's progression in a specific course.

For the dashboard implementations, we leveraged *ElasticSearch* as the underlying database and *Kibana* as the visualization tool. The data presented on the dashboard were specifically curated for this project and are stored in multiple .csv files.

Initially, our goal was to conduct a comprehensive data analysis using an extensive dataset found online. However, we faced significant challenges in locating suitable data that aligned perfectly with our needs. Consequently, we chose to create our own .csv files containing the essential data required to populate our dashboard.

This decision granted us full control over the data, enabling precise customization according to the specific requirements of our project. By curating our own dataset, we ensured the accuracy and relevance of the information presented, thereby facilitating a more insightful and effective implementation of our e-learning system. The data are shown on a time slice of twenty days, from May 1st to May 20th. The reason for this time interval is to illustrate the user's learning situation on the platform before the end of the courses, which is set for the last day of May.

Chapter 2

Data Description

To ensure that all identified requirements were met, it was decided, as previously mentioned, to use a dataset entirely created by us. This decision was driven by the need to have complete control over the variables and information present, thus ensuring that every required aspect was accurately represented and manageable. The dataset created consists of different CSV files, each one representing a table. These files describe the courses within an e-learning platform, the interactions between a user and courses, the interactions between users, the resources used by the user on the platform, and the user's results in the courses.

The files produced are tailored on the specific dashboard where used. These files are separated into two different directories: dashboard_1 and dashboard_2. The first directory contains the files used for the first dashboard which is related to the home of the platform, while the second directory contains the files used for the second dashboard which is related to a specific course. The files are named according to the information they contain, and the directory they are in.

The dataset is composed of the following tables:

- **Completed Course:** This table indicates whether the user has completed something each day or not for the different courses, the CSV file is named *./dashboard_1/completed_course_names.csv*;
- **Completed Modules:** This table indicates whether the user has completed something each day or not for the different modules, the CSV file is named *./dashboard_2/CourseCompletation.csv*;
- **User Hours Sessions:** This table represents the hours spent by the user on the platform each day and the average hours spent by other users, the CSV file is named *./dashboard_1/user_hours_sessions.csv*;
- **User Hours Sessions per Module:** This table represents the hours spent by the user for each module of a course each day and the average hours spent by other users, the CSV file is named *./dashboard_2/TimeSpent.csv*;
- **Resources:** This table represents the hours of use of the different resources that are available on the platform for each day, the CSV file is named *./dashboard_1/more_resources.csv*;
- **Resources per Course:** This table represents the hours of use of the different resources that are available for a course, the CSV file is named *./dashboard_2/MostUsedResources.csv*;
- **Forum:** This table represents the interactions between users on the forum, showing the number of questions asked, the number of answers given, and the number of answers received, the CSV file is named *./dashboard_1/forum_que_ans_given.csv*;

- **Forum per Module:** This table represents the interactions between users on the forum for each module of a course, showing the number of questions asked, the number of answers given, and the number of answers received, the CSV file is named *./dashboard_2/forum.csv*;
- **Completed Course Votes:** This table shows the votes obtained by the user for each completed test of the courses, categorized by type (theory or exercise), the CSV file is named *./dashboard_1/votes_courses.csv*;
- **Completed Modules Votes:** This table shows the votes obtained by the user for each completed module, categorized by type (theory or exercise), the CSV file is named *./dashboard_2/PracticeTheoryPerformance.csv*.

Chapter 3

Operational Concept

We questioned which requirement could be critical for a Situational Awareness System. This phase involved identifying and understanding the essential needs that the system must fulfill to be effective and user-friendly.

To achieve this, we conducted a detailed analysis of the *Operational Concept*, which involved the development of detailed personas and scenario analysis.

The Operational Concept is a critical phase in the design of complex systems, translating system requirements into actionable plans. It provides a comprehensive understanding of the system's operational environment, including the roles and responsibilities of the users, the tasks they perform, and the context in which they operate.

Since we are developing an e-learning dashboard intended for users who may access it from various locations, we have not defined specific environmental constriants. The flexibility of online learning environments means that users could be utilizing the system in diverse settings, such as homes, offices, or public spaces, each with varying levels of connectivity and hardware capabilities. Additionally, given the global reach of e-learning platforms, environmental conditions can differ widely among users, making it impractical to impose rigid environmental constraints.

3.1 Scenario

The company requires all employees to pursue upskilling or reskilling opportunities based on their previous studies and work experiences. Marta and Matteo are two employees whose skills and knowledge will be monitored to ensure they can effectively contribute to projects in the Offensive Cybersecurity field. The company's e-learning platform provides courses that enable employees to obtain the *OSCP* (Offensive Security Certified Professional) certification.

The platform is accessible both on-site at the company and remotely, offering flexible learning options that accommodate diverse schedules. Each employee receives a personalized dashboard where they can track their progress and access a wide range of educational resources, including video courses (concept pills), slide decks, and practical exercises. At the end of each module, employees can take assessments to reinforce their understanding and ensure they meet the learning objectives.

Additionally, the platform includes analytics and trend reports that help employees understand their learning journey, estimate the time required for course completion, and measure their engagement levels. The course design features a tailored approach, continuously monitoring each employee's performance and adapting to their specific learning needs. This customization

enhances the overall learning experience, ensuring employees are well-prepared for the OSCP certification.

3.2 Supported Figure: Matteo

Matteo is a student from the University of Salerno, with a bachelor's degree in Computer Engineering. His passion for cybersecurity has led him to specialize in this field, acquiring basic skills ranging from understanding the fundamentals of cybersecurity to networking and network protocols, from vulnerability analysis to familiarity with essential security tools. Now, Matteo faces a new challenge: a project in collaboration with Marta concerning Offensive Cybersecurity. However, to best address this task, Matteo needs to broaden his skills and knowledge.

Characteristic	**Description**
Age Range	20-25
Gender	Male
Culture	Italian
Education	Bachelor's degree in Computer Engineering
Language	Italian, English (proficient for technical literature)
Frequency of Use	Several times a week
Experience	Familiar with basic cybersecurity tools and platforms, intermediate programming skills
Personality	Curious, analytical, detail-oriented, enjoys problem-solving, goal-oriented, collaborative
Acquired Skills	Fundamentals of cybersecurity, networking, vulnerability analysis, basic scripting/programming, offensive cybersecurity
Learning Style	Visual and hands-on learner

3.3 Supported Figure: Marta

Marta is a student from the University of Naples Federico II. She completed a bachelor's degree in Computer Engineering and has now specialized in machine learning, acquiring basic skills in the field of artificial intelligence, including the structure and applications of neural networks and deep neural networks, their applications in robotics, and autonomous driving. Marta wants to collaborate with Matteo on a new project in the field of Offensive Cybersecurity. Since Marta has followed a different academic path from Matteo's, which does not involve cybersecurity, she needs to upskill her competencies.

Characteristic	**Description**
Age Range	20-25
Gender	Female
Culture	Italian
Education	Bachelor's degree in Computer Engineering, specializing in Machine Learning
Language	Italian, English (proficient for technical literature)
Frequency of Use	A few times a week
Experience	Skilled in AI and Machine Learning platforms, novice in cybersecurity
Personality	Innovative, inquisitive, enjoys learning new skills, collaborative, adaptable
Acquired Skills	Basics of AI, neural networks, deep learning, robotics, autonomous driving, basic programming, willingness to learn cybersecurity
Learning Style	Visual and auditory learner, prefers structured guidance

Chapter 4

Goal-Directed Task Analysis

We applied the *Cognitive Task Analysis* (CTA) methodology to explore individuals' knowledge and thought processes. Among the various CTA methodologies available, we selected *Goal-Directed Task Analysis* (GDTA), specifically focusing on Situation Awareness (SA) and the goals inherent in SA processes.

GDTA is tailored to identify user goals, the decisions they make, and the critical information needed to achieve these goals. This methodology not only maps out user objectives but also provides insights into their decision-making strategies and information requirements.

By employing GDTA, our aim is to deepen our understanding of how users perceive and interact with information. This understanding informs our design process, ensuring that our solutions align closely with user needs and preferences. Ultimately, this approach enhances the usability and effectiveness of our project outcomes by prioritizing User-Centric design principles.

4.1 Initial GDTA Goal Tree

The initial GDTA Goal Tree, shown in Figure 4.1, identified three Major-Goals. However, after an in-depth review and analysis, we concluded that the Major-Goal 1 **"Identify prior knowledge in the field of Cybersecurity"** can be integrated into the Major-Goal 2 **"Define and evaluate the knowledge required for Offensive Cybersecurity by monitoring students' progress"**. This conclusion was drawn from a comprehensive analysis of the sub-goals associated with Major-Goal 1.

Upon examining the sub-goals of Major-Goal 1, it became evident that both the sub-goals and the Major-Goal itself address topics that students need to master throughout their learning journey in cybersecurity. Given that Major-Goal 2 aims to delineate the specific topics and skills students must acquire, we decided to incorporate Major-Goal 1 as a sub-goal within Major-Goal 2. This integration ensures a more cohesive framework for evaluating and defining the necessary knowledge for Offensive Cybersecurity.

Furthermore, the sub-goals of Major-Goal 1 have been reclassified as Level 2 elements, signifying their importance in the comprehension phase of the learning process.

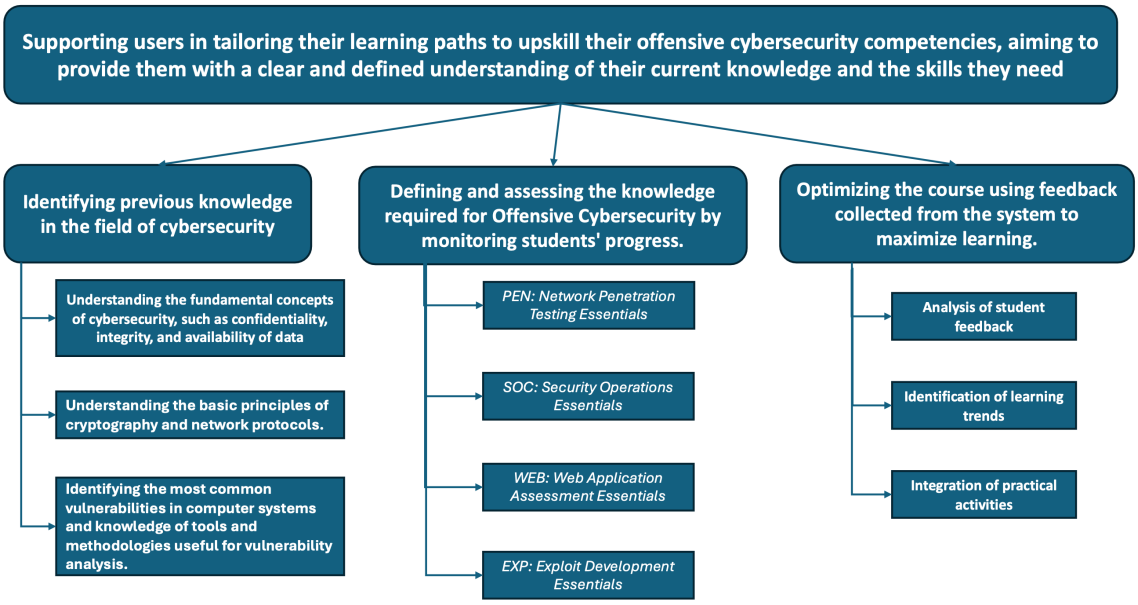

Figure 4.1: Initial GDTA Goal Tree

4.2 Final GDTA Goal Tree

In Figure 4.2, we present our Final GDTA Goal Tree, which outlines the primary goals of the system and the sub-goals that contribute to their achievement. In particular, our GDTA Goal Tree supports users in adapting their learning paths to enhance their expertise in Offensive Cybersecurity. The *Overall Operator Goal* is broken down into two primary *Major-Goals* as shown in the picture below. Each Major-Goal is further divided into *Sub-Goals* that are essential for achieving the Major-Goals.

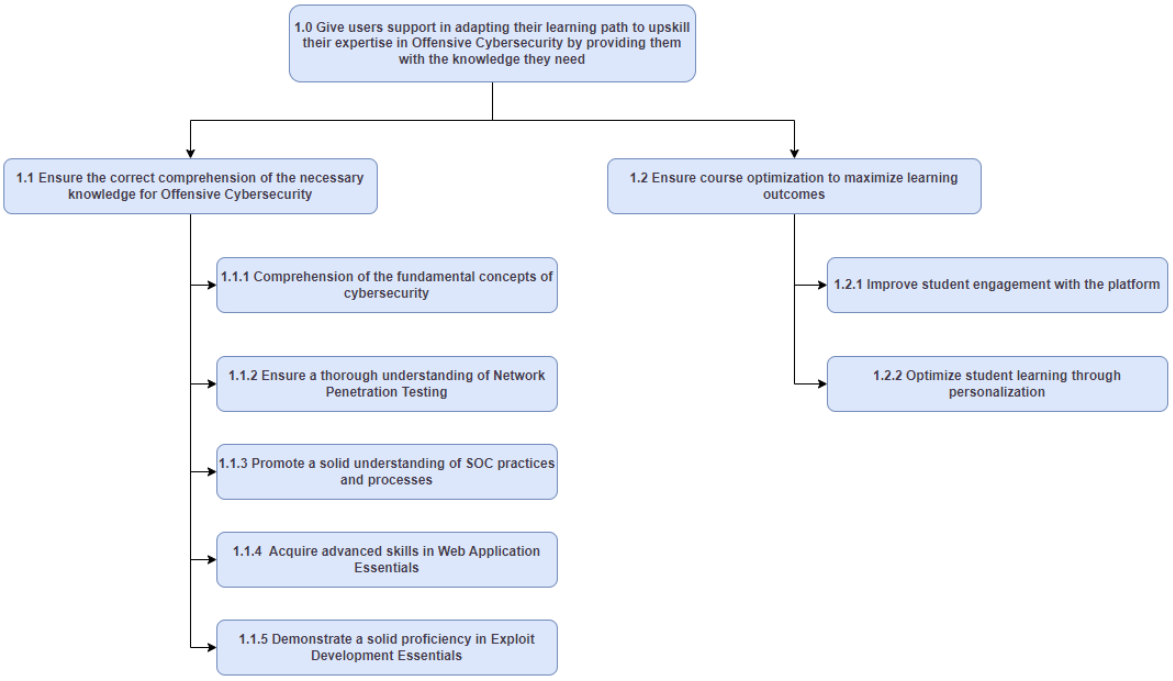

Figure 4.2: Final GDTA Goal Tree

The following sections will delve into the details of each sub-goal, providing a comprehensive understanding of the cognitive processes involved in achieving these objectives, rather than focusing on the methods or actions needed. Achieving these goals necessitates more complex cognitive processes than simply searching for a single piece of information.

Subsequently, we defined the *Informational Requirements* for each goal, which are crucial for users to make informed decisions and achieve their objectives. While these requirements might be mistakenly viewed as lower-level goals within the hierarchy, they actually serve as supportive elements that facilitate the achievement of primary goals.

In order to fulfill a goal, a decision must be made based on the available information. We are not interested in trivial yes-or-no questions: instead, we are focusing on decisions that enable the fulfillment of high-level goals. Moreover, these decisions require complex cognitive processes and a deep understanding of the situation.

4.3 Major-Goal 1.1: Ensure the correct comprehension of the necessary knowledge for Offensive Cybersecurity

In this section, we describe Major Goal 1.1 and its sub-goals. The main aim of this goal, along with its sub-goals, is to outline the modules that users need to study to enhance their skills. Essentially, this major goal represents how the course is structured in terms of modules that every student on the platform must learn.

We've taken a different approach compared to the typical GDTA (Goal Directed Task Analysis) process. The specific problem we're addressing (e-learning) isn't well-suited to the GDTA techniques typically taught in class. Therefore, we explain how we've proposed sub-goals and levels of perception, comprehension, and projection for these sub-goals.

The objective of this major goal is to enable all platform users to acquire Offensive Cybersecurity knowledge. Although the sub-goals may initially seem like tasks, they are intended as individual objectives that each student must achieve to solidify their understanding of the field.

There are no time constraints for achieving these individual objectives, allowing students to start studying whichever module they prefer and proceed at their own pace. This approach enables users to create a personalized learning path: they can skip modules they already know and only take end-of-module tests, or revisit topics where they feel they need more practice based on platform recommendations.

Regarding *Perception Level*, we've included the fundamental concepts of each course that students perceive, focusing on concise micro-learning. For instance, topics such as firewall, PHP, and SHA256 are covered in concept pills.

At the *Comprehension Level*, we've incorporated broader concepts that connect one or more micro-learning modules. The goal is to help students understand concepts that emerge after assimilating micro-learning, such as data integrity through understanding algorithms like MAC combined with SHA256.

Finally, at the *Projection Level*, we've identified the advanced competencies that students acquire through comprehension and perception, such as the ability to apply learned methodologies in future scenarios.

4.3.1 Sub-Goal 1.1.1: Comprehension of the fundamental concepts of cybersecurity

The objective of comprehending the fundamental concepts of cybersecurity is to provide individuals with a robust understanding of essential security principles and practices. Key areas of focus include ensuring confidentiality through mechanisms like OTP and MAC, maintaining data integrity with tools such as SHA256, and guaranteeing availability via digital signatures. Additionally, an understanding of blockchain technology and threat models is crucial, along with proficiency in cybersecurity algorithms and protocols like TLS. This foundational knowledge enables individuals to critically evaluate emerging technologies in relation to IT security and stay informed about current laws and regulations. The decision associated with subgoal 1.1.1 and its SA requirements are shown in the following figures.

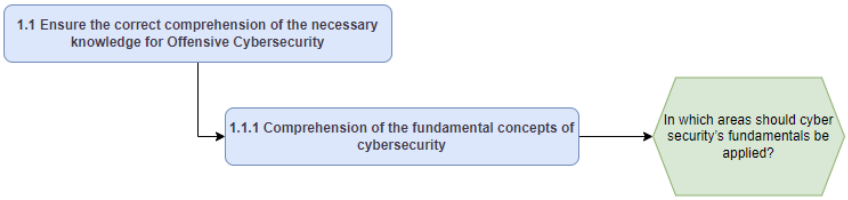

Figure 4.3: Sub-Goal 1.1.1

Level 1 SA requirements	**Level 2 SA requirements**	**Level 3 SA requirements**
CPA Security	Confidentiality	Capability to critically evaluate emerging technologies in relation to IT security, current laws and regulations
SHA256	Integrity	
Advanced Schemes	Availability	
Zero Knowledge Proof	Threat Models	
Blockchain	Algorithms for Cybersecurity	
TLS Protocol		
Public Key		

Table 4.1: SA requirements for subgoal 1.1.1

4.3.2 Sub-Goal 1.1.2: Ensure a thorough understanding of Network Penetration Testing

The objective of ensuring a thorough understanding of network penetration testing is to equip individuals with the necessary skills and knowledge to effectively identify and mitigate security vulnerabilities within network infrastructures. This includes mastering fundamental programming concepts such as Python operators, syntax, and Powershell scripting, as well as understanding key network protocols like the Internet Protocol (IP) and Domain Name System (DNS). Advanced competencies involve applying cryptography techniques and hashing, acquiring in-depth Windows networking knowledge, and efficiently using variables, loops, and functions in Python and Powershell. Ultimately, this comprehensive understanding enables individuals to select the most appropriate penetration testing strategies for various scenarios, ensuring robust network security. The decision associated with subgoal 1.1.2 and its SA requirements are shown in the following figures.

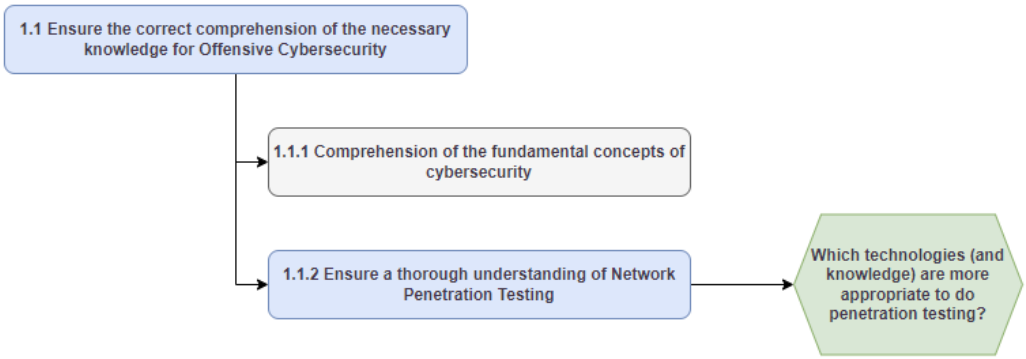

Figure 4.4: Sub-Goal 1.1.2

Level 1 SA requirements	Level 2 SA requirements	Level 3 SA requirements
Python operators	Cryptography techniques and hashing	Capability to choose the best penetration testing strategies based on the situation
Python syntax	Windows networking knowledge	
Powershell Scripting	Usage of variables	
Internet Protocol	Loops and functions in Python and Powershell	
Domain Name System		

Table 4.2: SA requirements for subgoal 1.1.2

4.3.3 Sub-Goal 1.1.3: Promote a solid understanding of SOC pratices and processes

The objective of promoting a solid understanding of Security Operations Center (SOC) practices and processes is to provide individuals with the knowledge and skills necessary to effectively manage and respond to cybersecurity incidents. This includes foundational knowledge of network protocols such as the Internet Protocol (IP) and Domain Name System (DNS), as well as scripting skills with Powershell. Advanced competencies involve data conversion in Python between decimal, binary, and hexadecimal formats, understanding operational security and security management, and familiarity with practices such as the Cyber Kill Chain and logging. Ultimately, this comprehensive understanding enables individuals to proficiently detect and respond to cyber threats, ensuring robust security operations. The decision associated with subgoal 1.1.3 and its SA requirements are shown in the following figures.

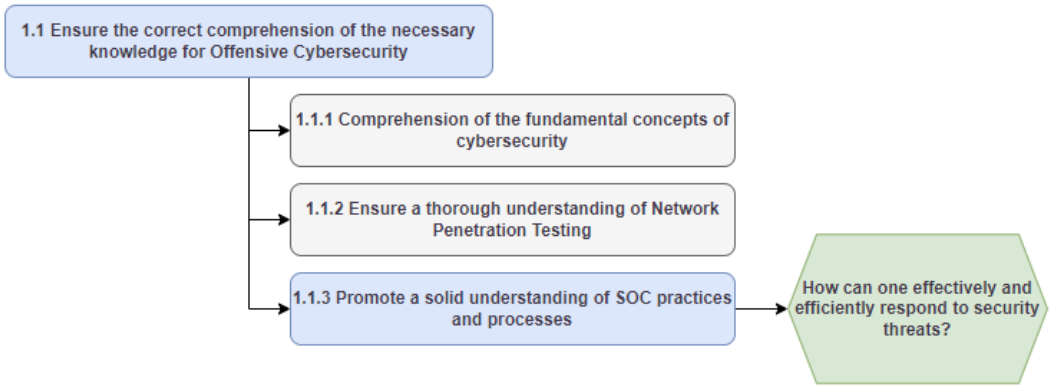

Figure 4.5: Sub-Goal 1.1.3

Level 1 SA requirements	Level 2 SA requirements	Level 3 SA requirements
Internet Protocol	Data conversion in Python between decimal, binary, and hexadecimal	Knowing how to detect and respond to cyber threats
Powershell Scripting	knowledge of operational security and security management	
Domain Name System	practices of Cyber Kill Chain and Logging	
Firewall		

Table 4.3: SA requirements for subgoal 1.1.3

4.3.4 Sub-Goal 1.1.4: Acquire advanced skills in Web Application Essentials

The objective of acquiring advanced skills in web application essentials is to enable individuals to develop and maintain secure web applications. This encompasses foundational knowledge of web development technologies such as HTML, CSS, PHP, and JavaScript, along with proficiency in security tools like ZAP, AFL, SonarQube, and Flawfinder. Advanced skills include managing secure sessions, handling authentication, authorization, passwords, and cookies, and ensuring the security of REST, SOAP, and GraphQL services, as well as security practices in GIT. Ultimately, this comprehensive understanding equips individuals to recognize and mitigate vulnerabilities such as Server Side and Client Side XSS, Cross-Site Request Forgery, Clickjacking, and Content Sniffing, thereby ensuring robust web application security. The decision associated with subgoal 1.1.4 and its SA requirements are shown in the following figures.

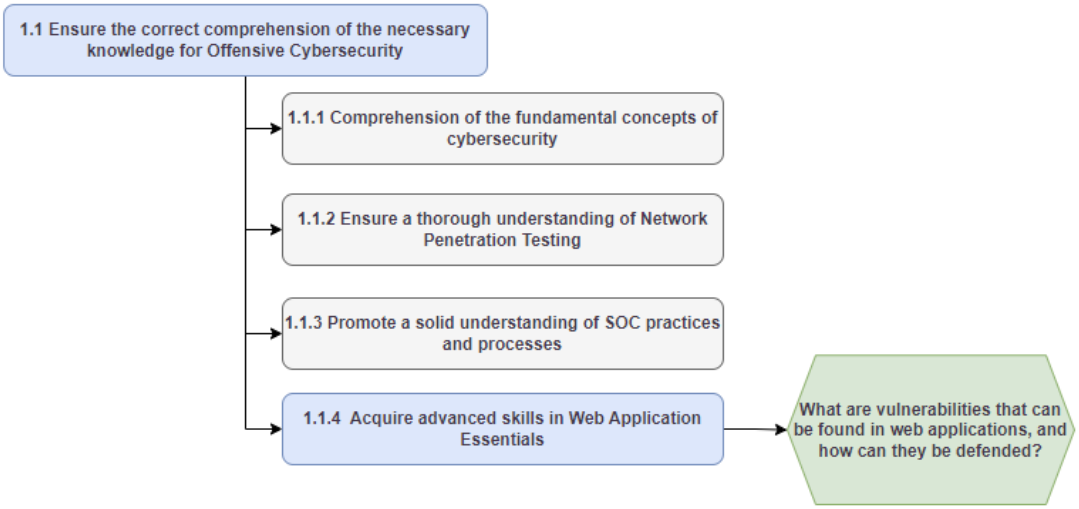

Figure 4.6: Sub-Goal 1.1.4

Level 1 SA requirements	Level 2 SA requirements	Level 3 SA requirements
HTML, CSS, PHP, Javascript	Managing secure sessions, including authentication, authorization, passwords, and cookies, REST, SOAP and GraphQL services, security in GIT	Understanding how to make a secure web application
ZAP		Recognizing Server Side & Client Side XSS, Cross-Site Request Forgery, Clickjacking, Content Sniffing
AFL		
SonarQube, Flawfinder		

Table 4.4: SA requirements for subgoal 1.1.4

4.3.5 Sub-Goal 1.1.5: Demonstrate a solid proficiency in Exploit Development Essentials

The objective of demonstrating solid proficiency in exploit development essentials is to enable individuals to effectively identify and develop exploits for various security vulnerabilities. This includes foundational knowledge of network protocols, VPNs, and firewalls. Advanced competencies involve understanding ARM-32 and ARM-64 assembly, manipulating registers, stacks, and functions, and analyzing binary files. Ultimately, this comprehensive skill set allows individuals to understand how malicious scripts affect applications, identify flaws in security measures, and leverage exploit frameworks to enhance cybersecurity defenses. The decision associated with subgoal 1.1.5 and its SA requirements are shown in the following figures.

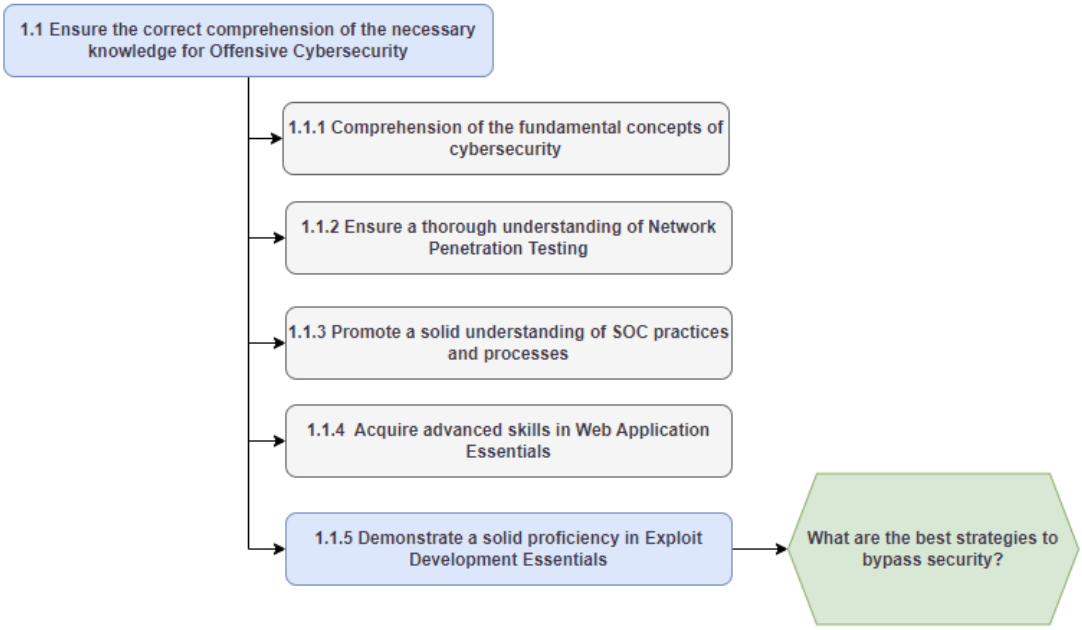

Figure 4.7: Sub-Goal 1.1.5

Level 1 SA requirements	Level 2 SA requirements	Level 3 SA requirements
Network Protocols	Assembly for ARM-32 and ARM-64	Understanding how a malicious script affects an application
VPN	Registers, stacks and functions	Ability to identify flaws in security measures
Firewalls	Analysis of binary files	Knowledge of exploits frameworks

Table 4.5: SA requirements for subgoal 1.1.5

4.4 Major Goal 2.1: Ensure course optimization to maximize learning outcomes

This Major-Goal aims to make the platform more engaging and effective for users. It focuses on two main things: boosting how users interact with the platform and making studying more personalized based on how each user learns.

To achieve this, the platform will track how users use it—what they're interested in, what skills they have, and where they might need help. With this info, the platform can suggest topics for users to review and adjust how it works to match each user's progress and preferences. This will make learning easier and more effective, helping users reach their goals faster.

4.4.1 Sub-Goal 2.1.1: Improve student engagement with the platform

The objective of improving student engagement with the platform focuses on increasing and enhancing student interactions. Key metrics include the frequency of logins, session length, click-through rates on content, return visits, retention rates, and forum activity (questions and answers). Comparative analyses involve user login frequencies versus average rates, material usage percentages, and forum activity levels. Ultimately, the goal is to prevent student dropout by understanding and addressing engagement factors. The decision associated with subgoal 2.1.1 and its SA requirements are shown in the following figures.

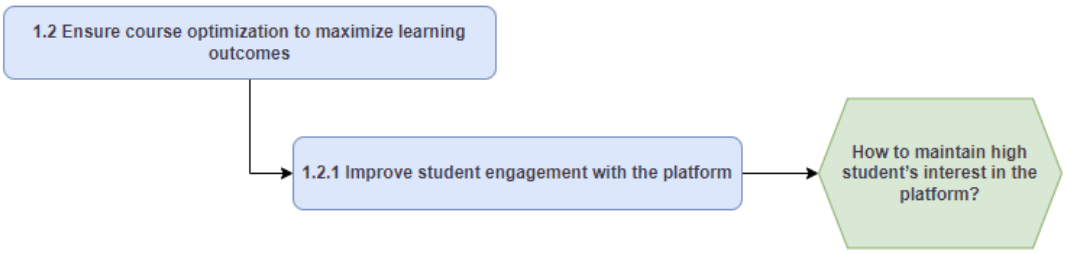

Figure 4.8: Sub-Goal 2.1.1

Level 1 SA requirements	**Level 2 SA requirements**	**Level 3 SA requirements**
Number of active users	Comparison between students session lengths	Preventing student dropout
Session length	Comparison between students days spent on module	
Days spent on module	Student interaction within the forum	
Number of answers on the forum		
Number of questions on the forum		
Number of notifications on the forum		

Table 4.6: SA requirements for subgoal 2.1.1

4.4.2 Sub-Goal 2.1.2: Optimize student learning through personalization

The objective of optimizing student learning through personalization is to enhance educational effectiveness by tailoring the learning experience to individual student needs and preferences. This involves assessing student performance through end-of-module assessments and tracking course completion rates to understand overall engagement. Additionally, it requires analyzing trends in student performance over time to identify areas for improvement. Furthermore, the initiative aims to optimize learning by monitoring resource reuse, identifying areas of difficulty and preferred learning styles, and evaluating the acquisition of specific skills. By leveraging these insights, the goal is to create a more personalized educational environment that supports and enhances student learning outcomes effectively.

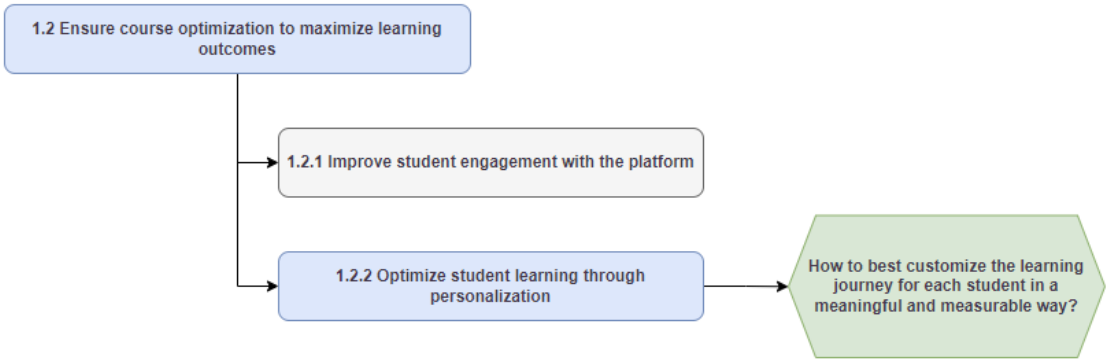

Figure 4.9: Sub-Goal 2.1.2

Level 1 SA requirements	**Level 2 SA requirements**	**Level 3 SA requirements**
End-of-module test scores	Percentage of completed course	Trends in student performance over time
Modules visited	Problem-Solving vs Memory Performance	
Used material	Percentage of usage of the different kinds of materials provided to the students showing their preferences	
	Skill types and areas of difficulty	

Table 4.7: SA requirements for subgoal 2.1.2

Chapter 5

Context Space Theory

The *Context Space Theory* is a theory in the field of cognitive science and computational linguistics that uses multidimensional spaces to represent the meaning of words (and sentences) in respect to the context in which they appear.

Multidimensional spaces are called *Context Spaces*. Context features are called *Context Attributes* and are represented as an axis of the multidimensional space. The set of situations that may occur is called *Situation Space*.

5.1 CST For Engagement Level

We decided to use the CST to assess the student's engagement level on the platform. This is a particularly useful parameter to show the user whether his/her use of the platform complies with the requirements and is shown on the dashboard through a badge.
We decided that the data to be used for CST will be taken from the last 7 days with the following clarifications:

- If the user has been using the platform for less than 7 days, the CST will not be applied and the badge will have a gray (neutral) color.
- The CST is applied dynamically every day, on the data from the last 7 days (using a sliding window), thus allowing the user to adapt dynamically.

5.1.1 Situation Space

In our Situation Space we identify 3 situations:

- High engagement;
- Medium engagement;
- Low engagement.

The situation the student is in will be given by a weighted summary of the context attributes considered.

5.1.2 Context Attributes

Before defining context attributes, it's important to define the attributes to consider:

- Session length;
- Questions on the forum;

- Unanswered questions on the forum;
- Used material.

These attributes are considered relevant because:

- Session length shows how much time the user spends on the platform;
- The number of questions made on the forum shows how engaged the user is with the forum;
- The number of unanswered questions shows which of the questions asked are possibly not relevant to other platform users;
- The amount of material used shows whether the user finds the provided material useful.

To go from attributes to context attributes, we must specify, for each attribute, a membership function that "maps" the values assumed by the attribute to a range from 0 to 1.

F_SL

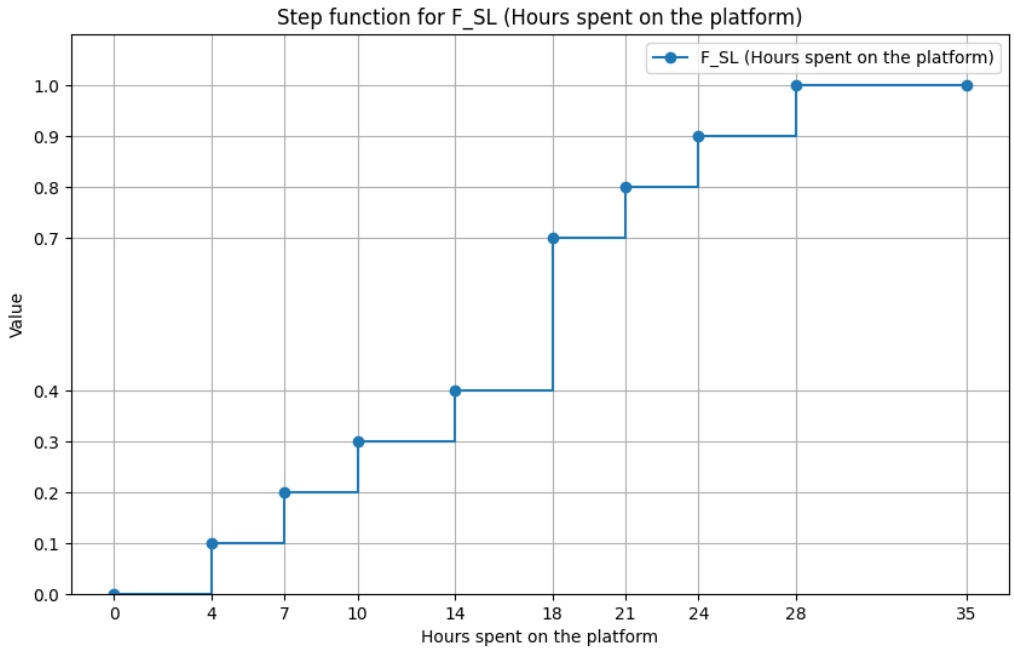

Figure 5.1: F_SL Membership Function

This function is implemented this way because the company would prefer that users spend 28 hours per week on the platform. A higher number of hours is not rewarded further. At 18 hours there is a gap because the company wants to differentiate those who use the platform greatly from those who use it lightly.

F_FQ

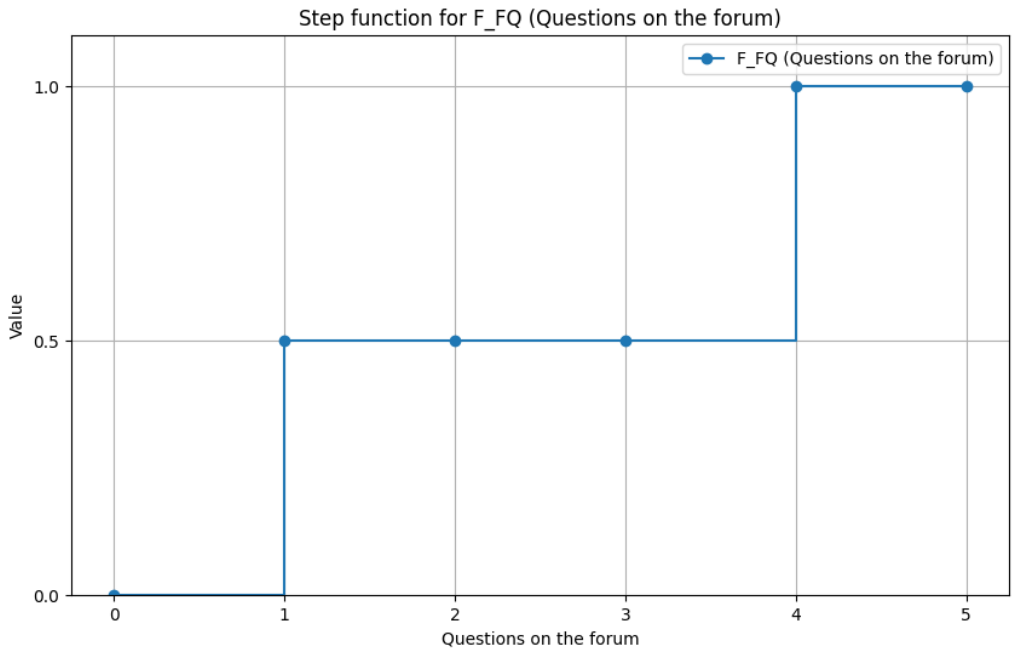

Figure 5.2: F_FQ Membership Function

This function is implemented this way because the company wants to differentiate between those who do not ask questions, those who ask some questions, and those who ask many questions.

F_NA

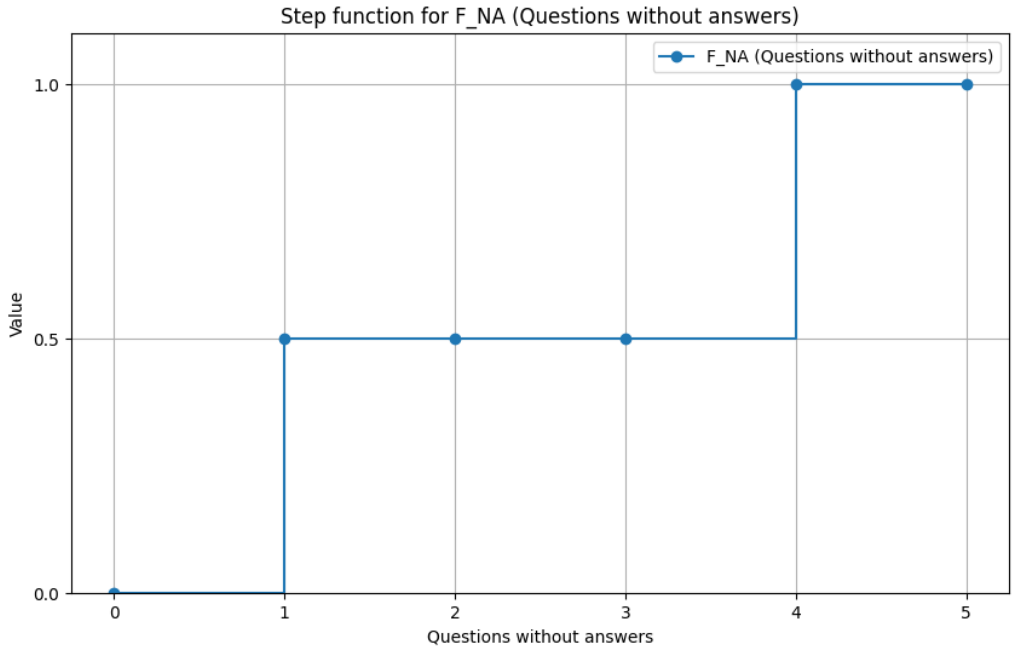

Figure 5.3: F_NA Membership Function

This function is made this way because the company wants to understand whether users' questions catch the attention of others or not.

F_M

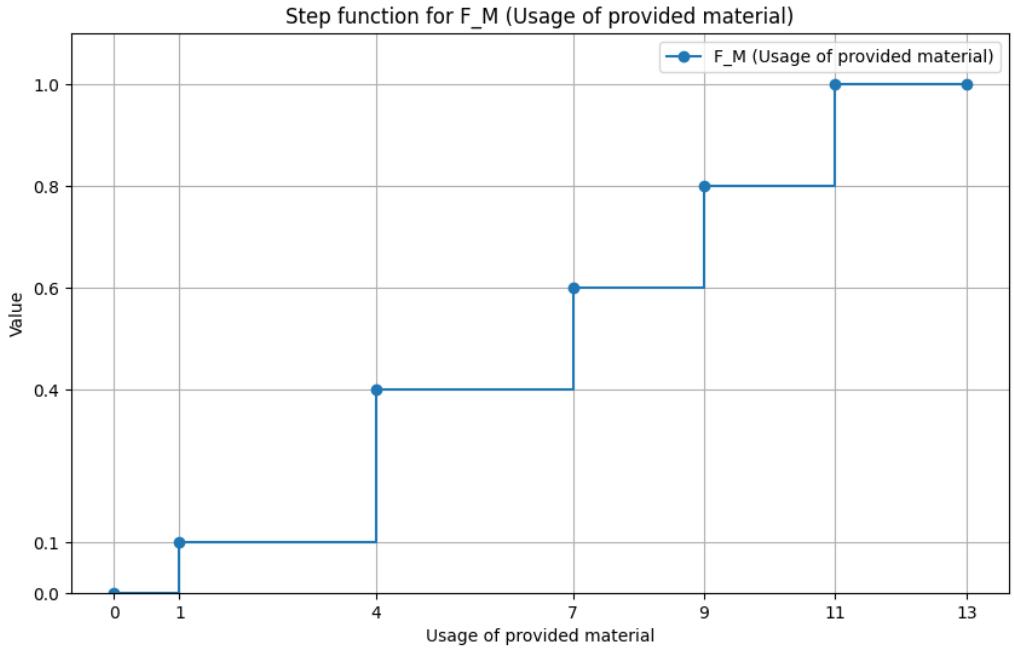

Figure 5.4: F_M Membership Function

This function is implemented this way because the company wants the provided material to be partitioned equally over the entire duration of the training. The optimal amount is 11; using more is not rewarded further.

5.1.3 Weights and situation calculation

Each context attribute has an associated weight. F_SL, F_FQ and F_M are considered positive factors, where F_SL is considered to be the most important. F_NA is considered a negative factor with low relevance. This decision was made on the assumption that unanswered questions did not pique the interest of other users probably because they were not relevant in the context in which they were asked. Viewing this factor as negative penalizes those who ask an excessive number of questions on the forum in order to try to increase their engagement.

Attribute	**Context attribute**	**Weight**
Session length	F_SL	0.56
Questions on the forum	F_FQ	0.12
Unanswered questions on the forum	F_NA	-0.1
Used material	F_M	0.32

Table 5.1: Context attributes table

To calculate the situation a student is in, we use the following formula:

$$S = \sum_{i=1}^{3} w_i \cdot CA_i$$

Where:

- CA_i is one of the context attributes defined above
- w_i is the relative weight
- i=0,1,2,3

Extended form formula:

$$S = w_{SL} \cdot F\_SL + w_{FQ} \cdot F\_FQ + w_{NA} \cdot F\_NA + w_M \cdot F\_M$$

5.2 Simulation

We simulated on two time intervals. The first data is taken after 7 days from when the users signed up in the platform (for simplicity, we will refer to this data as "week 1"), while the second taking was done after 12 days (for simplicity, we will say "week 2"). Six users are considered.
During week 1:

- Aldo and Matteo do not stay much on the platform. They use about half of the planned material and they decide that it is easier to ask many things on the forum.
- Maya and Matilde use very little material but they still ask some questions on the forum. They know the platform is monitoring them so they decide to leave their devices on idle on the platform.
- Filippo and Marta are very interested on the topics they are studying and use the planned material for the week. Hovewer, Filippo does not find the forum very useful while Marta the exact opposite.

The results:

Name	Engagement Level
Aldo	Low
Filippo	High
Marta	High
Maya	Medium
Matilde	Low
Matteo	Low

Table 5.2: Results for Test Case Week 1

During week 2:

- Aldo wants to make up for his shortcomings. He spends more time on the platform and is very interested in multimedia content.
- Filippo and Marta are still working very hard. Filippo has a personal commitment and spends less time on the platform than in the previous week.
- Maya decides to stop cheating. She does not use the forum, spending all her time reading and studying.
- Matilde wants to continue cheating. She thinks she needs to spend even more time online and ask even more questions.

- Matthew continues his trend from the previous week. He completes more material, meanwhile, he interacts less on the forum. All his questions are answered.

The results:

Name	Engagement Level
Aldo	High
Filippo	Medium
Marta	High
Maya	Medium
Matilde	Medium
Matteo	Medium

Table 5.3: Results for Test Case Week 2

These results show the achievement of our idea of engagement:

- The most important element is the number of hours spent on the platform. You are able to cheat by leaving devices on but with poor results without at least interacting with the forum.
- With a good number of hours and a good amount of material used engagement drops if there is no interaction with the forum (unless the other parameters are perfect).
- The system is adaptive. The result can be recovered if user performance improves and, also inversely, it drops as performance worsens.

5.3 Dashboard Integration

The CST is integrated into the dashboard through the script *elasticsearch_read_injection.py*. This script creates a connection with Elastic Search, takes data from the *users_context_attributes* index present inside Elastic Search (i.e., the data corresponding to week 1 of the simulation) and, for each user in the index, computes the corresponding engagement level, which is used to update the badge in the main dashboard. The values are then injected into Elastic Search in the *users_engagement_level* index.

Chapter 6

Dashboard

This paragraph will present the two dashboards implemented, the design principles used, and the SA demons that were tried to avoid. As mentioned before, to ensure that most of the requirements identified in the previous stage could be represented, it was decided to use a dataset entirely created by us to have full control over the data and its structure.

The whole system is divided into two dashboards, each associated with multiple goals. The first dashboard aims to establish **Common Operational Picture** that allows students to have an understanding of the current situation by integrating multiple subgoals into coherent visualizations. Unlike, the second dashboard, focuses on tracking and presenting student learning progress within a specific course.

- **Dashboard I**: Subgoal 1.2.1 - Improve student engagement with the platform and Subgoal 1.2.2 - Optimize student learning through personalization.
- **Dashboard II**: Subgoal 1.1.1 - Comprehension of the fundamental concepts of cybersecurity, Subgoal 1.2.1 - Improve student engagement with the platform and Subgoal 1.2.2 - Optimize student learning through personalization.

Both of the dashboards attempt to achieve the trade-off between supporting the operator's goal and supporting the overall SA. By placing the most important information appropriately at the center of each dashboard and positioning the supporting information on the sides, we ensure that relevant data is easily accessible to the student. This design choice is intended to reduce the cognitive load on the student, so he/she can quickly understand his current situation and make informed decisions about his learning path.

6.1 Dashboard I

The objectives of this dashboard are to maintain student engagement with the platform and to assist in tailoring the learning process to meet the student's needs.

To ensure the student is aware that they are on the home page of the platform, the name **OffSec** is included, representing *Offensive Cybersecurity*. Additionally, a "Welcome Marta!" message is displayed to emphasize that this dashboard is the home page. These two elements help prevent the student from using an incorrect mental model when interpreting the dashboard's components, effectively avoiding the **Wrong Mental Model** demon.

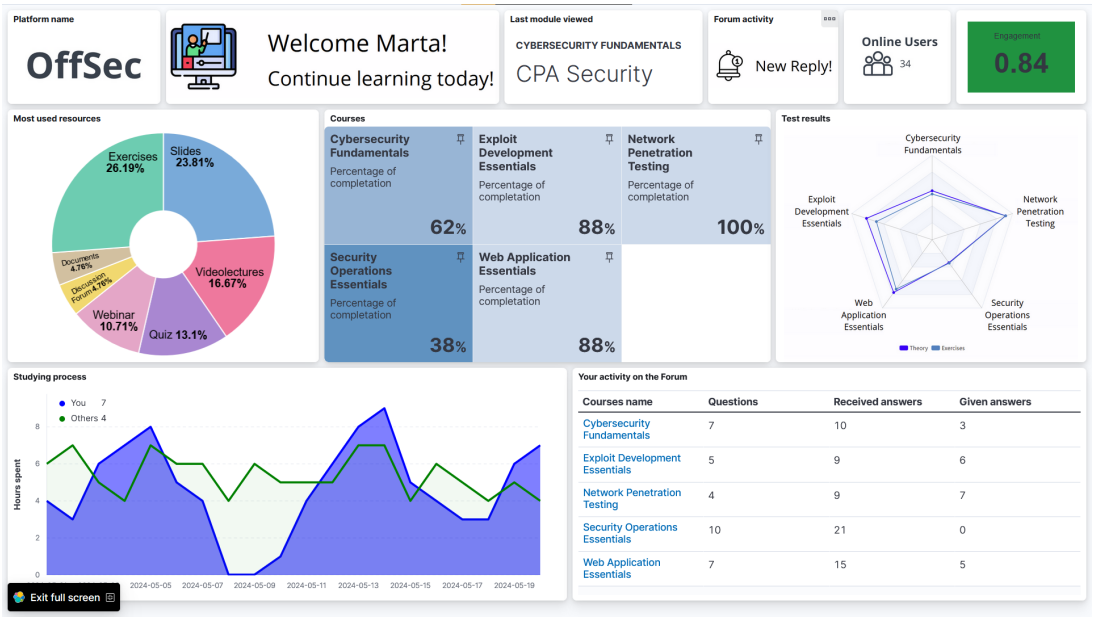

Figure 6.1: Dashboard I

To ensure compliance with **Design Principle 4** and in order to support **Design Principle 1**, the dashboard should be designed with central elements supporting specific goals, surrounded by elements that provide an overview of the student's progress. But typically, e-learning systems display an overview of the courses the student is following. Therefore, we adopted this common approach for our system as well. As shown in Figure 6.1, the center of the screen features a matrix of the various courses the student needs to complete for upskilling, with each course's completion percentage clearly indicated. This allows students to quickly understand their progress, supporting their overall SA.

This design choice supports both **Design Principle 5 and Design Principle 6** through the effective use of salience. Darker colors in the matrix highlights courses with lower completion percentages, drawing the student's attention to these areas and guiding the student towards the courses that need more attention before their deadlines. This can prompt a shift from data-driven to goal-driven behavior, encouraging the student to prioritize completing the less finished courses.

In order to form the right Global SA of the student, on the right side of the screen there is a spider chart showing the results of the student on theoretical tests and practical tests, weighted on the number of tests completed for the course. Instead, on the left side of the screen, there is a donut chart, that shows which resources the student has preferred for the different courses the student has used, in order to support the **Subgoal 1.2.2**.

The linear graph, which shows the student's time spent on the platform since the start of the upskilling process, supports **Subgoal 1.2.1**. It allows the student to compare his/her time spent on the platform with the time spent by other students. By observing this graph, the student can become aware of his/her own hours invested. If the student notices that other students have spent significantly more time on the platform, it can serve as a motivation for him/her to dedicate more time to the learning process. This comparative visualization encourages students to increase their engagement and commitment to the platform, cultivating a more competitive and driven learning environment.

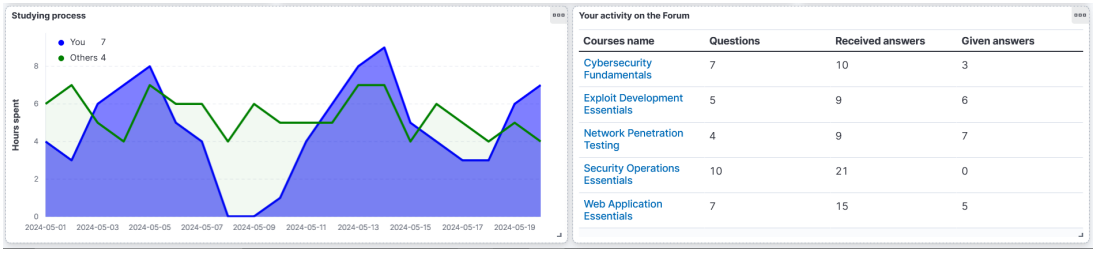

Figure 6.2: Dashboard I - Subgoal 1.2.1

The elements present in Figure 6.3 indicate student engagement with the platform, presenting (from right to left) the computed engagement level using the CST described in a previous chapter, the number of students currently online, a notifications section from the forum, and an element displaying the last viewed module. Together, these components maintain continuous global situational awareness to prevent the occurrence of the **Attentional Tunneling** demon. In particular, the last viewed module element helps to avoid the **Memory Trap** demon by providing a quick reminder of the student's most recent activity, reducing the cognitive load associated with remembering the last module they accessed.

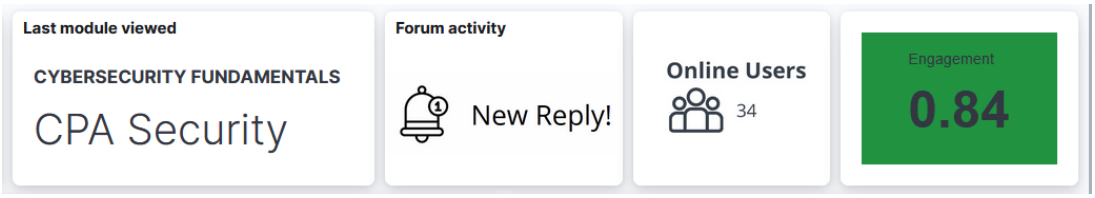

Figure 6.3: Dashboard I - Global Top

Given that human attention and working memory are limited, most of the information has been processed and integrated in terms of Level 2 SA, supporting comprehension. Therefore, **Design Principle 2** has been satisfied. This allowed us to avoid the **Memory Trap** demon, which can occur when students are required to remember too much information. Moreover, the use of visualizations such as the spider chart and the donut chart helps to avoid the **Data Overload** demon and the **Complexity Creep** demon, as they provide a more compact representation of the data, reducing the amount of information that needs to be processed.

Another element that could contribute to support the **Design Principle 5** is the presence of the notifications from the forum, which can capture the student's attention and facilitate the switch between goal-driven and data-driven processing. This element helps to avoid the **Attentional Tunneling** demon.

The engagement level element is displayed as a square shape filled with a color, which can capture the student's attention when it is not needed, causing a bit of the **Misplaced Salience** demon. Though, the use of colors (green, yellow, orange) suggests that if the indicator is green, the student's attention may briefly focus on it, indicating satisfaction or a certain level of confidence in their engagement level. Unlike the yellow and orange colors that might encourage the student to spend more time on the platform and interact more actively with it.

The dashboard effectively prevents the **Out of the Loop** demon since there are no autonomous functions that operate independently and since it is crucial for the student to make decisions about their actions and timing autonomously.

Our goal is also to fulfill **Design Principle 3**, which emphasizes providing Level 3 assistance. This is facilitated within our dashboard through the inclusion of a forum. By interacting with

other users to discuss course-related questions and challenges, students can obtain answers and support. This interaction could encourage them to continue their learning journey, thereby reducing the likelihood of abandoning the platform.

6.2 Dashboard II

The goal of the dashboard is to support the operator's objective of understanding the student's learning progress within a specific course. It is characterized by a title **Cybersecurity Fundamentals** to indicate the course the student is currently focusing on. The inclusion of a specific course title on the dashboard plays a crucial role in preventing user confusion, especially given the variety of courses a student might be enrolled in.

This clear indication of the course focus helps to avoid the misinterpretation of information, which is particularly important under conditions of high environmental or emotional stress. By doing so, it directly addresses and mitigates the risk of the **Wrong Mental Model** demon, ensuring that students maintain an accurate understanding of their learning progress and requirements within the context of the specific course they are viewing.

Some common guidelines were used to blend the user experience and create a sense of confidence in switching between the different dashboards and to enhance efficiency by transporting the experience matured in one dashboard to the other. This is helpful so that the operator can create expectations about the interface, increasing his or her satisfaction.

Principle 8 guided the design of the entire dashboard, since information is not shown as it is obtained in order to avoid the **Data Overload** demon since it can increase the complexity of the dashboard and make it difficult to have a comprehensive understanding of the situation. The choice of different data visualizations used made it possible to reduce the effects of the **Data Overload** demon as well, by being able to convey the same information by expressing it in graphical form rather than in textual or tabular form (e.g., pie charts for the most used resources), reducing the cognitive load on the student.

A first view of the second dashboard is shown in the following figure.

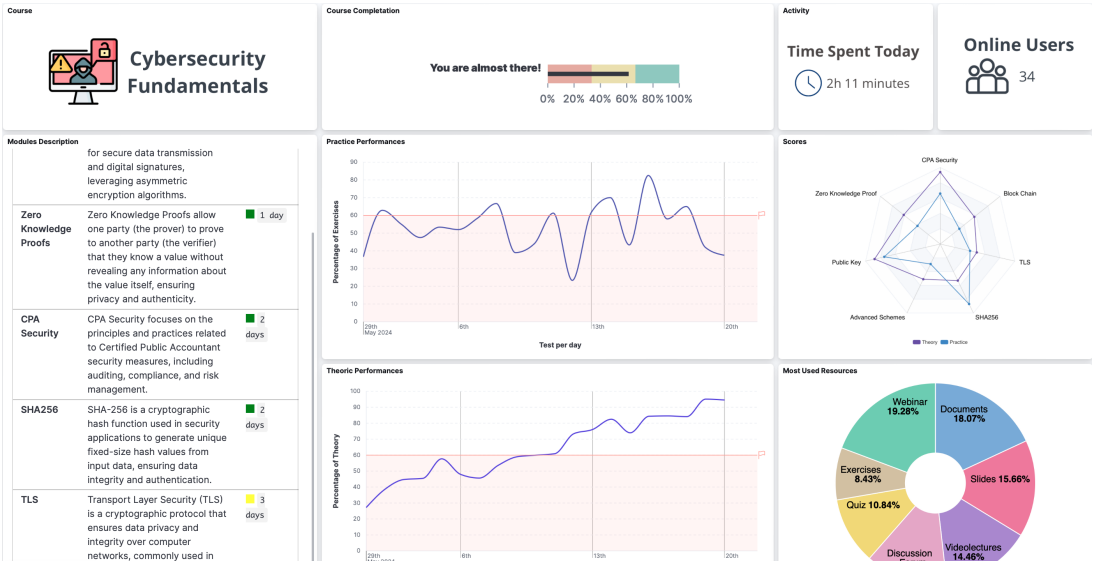

Figure 6.4: Dashboard II

With multiple subgoals active on the dashboard, it's important that when a student opens it, they can quickly figure out the necessary information to achieve their objectives.

This follows **Design Principle 1**, which ensures that information is provided effectively to support decision-making. When a student clicks on a course, they will see charts in the center of the dashboard showing their progress and course completion status.

These charts, like the others on the dashboard, also satisfy **Design Principle 2** because the interface provides already processed and integrated information at level 2. Specifically, the data levels (level 2 and level 1) allow for a complete understanding of a critical situation, such as the student's performance in the course, without the need for further processing.

To ensure that salience is appropriately balanced within the dashboard, emphasis is placed only on information considered important. For instance, the red threshold line in the main charts indicates that if a student's end-of-module test scores fall below 60%, they need to decide on a strategy for improvement. This visual cue helps students understand that they should aim for scores above this threshold.

Additionally, the estimated completion days for each module, where all the modules are listed with their description, are highlighted in red if they exceed four days, based on data from previous users who have taken the course. This alerts students that they may need to put in more effort for these particular modules. The use of red to draw attention to critical areas complies with Design Principle 6, clearly signaling to the student where they need to focus and prompting them to take corrective action if necessary.

The dashboard also includes a gauge chart dedicated to overall course completion. If a student has completed less than 40% of the course, this chart will highlight the need for increased attention to ensure timely course completion. The addition of a course completion chart helps reduce the cognitive load on users by offering a visual depiction of their progress. This feature was intentionally introduced to prevent users from having to remember the completion percentage shown on the main dashboard. By replicating this information across subsequent dashboards, our goal is to overcome the challenge of relying on memory (facing the Memory Trap demon), which can often not guarantee accurate awareness and decision-making.

These design choices also support **Design Principle 3** by providing level 3 projection assistance. This means that if a student maintains consistent performance across multiple modules, it can be projected that they will likely perform well in future modules.

Given that the dashboard supports three subgoals, it is likely that when a student first opens the dashboard for a specific course, they do so to check their understanding of the fundamental cybersecurity concepts. Through various charts—such as those showing their theoretical and practical test performance, course completion status, and average grades, they can assess their level of understanding of the course. This also supports the subgoal related to optimizing learning through personalization, including a pie chart that shows the usage of different learning materials for each module in order to show a student learning preferences.

The other charts support goals related to engagement with the platform. For example, these include activities in the forum, engagement level badges obtained from the CST, the number of users online at the time of access, the time spent on the platform, and the days taken to complete each module compared to other students.

Therefore, we assume that at first glance, the student decides to focus on the first subgoal **Comprehension of the fundamental concepts of cybersecurity** to reach their objective and then potentially switches to other supported goals as they shift their attention to the other charts. This approach satisfies Design Principle 5 and Design Principle 4 by including elements in the dashboard that capture attention on aspects satisfying different goals. This prevents attention from being confined to a limited set of information, thereby overcoming the issue of attentional tunneling and supporting the switch between goal-driven and data-driven modes

based on the goal the student wishes to achieve.

Chapter 7

Conclusions

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