PROGRESSIVE MICROSERVICES BLENDED LEARNING EDUCATIONAL PLATFORM

by

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Περίληψη

Η εκπαίδευση σήμερα έχει όλο και περισσότερη ποικιλομορφία στην τάξη, γεγονός που αυξάνει την ανάγκη για εξατομικευμένες πλατφόρμες μάθησης που υποστηρίζουν την ανάπτυξη δεξιοτήτων του 21ου αιώνα. Η εξατομικευμένη μάθηση είναι κρίσιμη για την ανάπτυξη των γνωστικών και διαπροσωπικών ικανοτήτων που απαιτούν οι μαθητές σήμερα. Οι πλατφόρμες που στοχεύουν στην επίλυση αυτού του ζητήματος θα πρέπει να υποστηρίζουν την ανάπτυξη προσαρμοστικού μαθησιακού περιεχομένου, υλικού σχεδιασμένου από δασκάλους και να παρέχουν αποτελεσματικά εργαλεία στους εκπαιδευτικούς για να επιτρέπουν τη δημιουργία εξατομικευμένων φύλλων εργασίας που συνδέονται με συγκεκριμένα γνωστικά επίπεδα και εκπαιδευτικούς στόχους. Οι εκπαιδευτικοί σήμερα αντιμετωπίζουν πολλές προκλήσεις στη δημιουργία φύλλων εργασίας προσπαθώντας να επιτύχουν διδακτικούς στόχους για ένα ποικίλο σύνολο προφίλ μαθητών. Υπάρχουσες συμβατικές πλατφόρμες που χρησιμοποιούν εκπαιδευτικά συστήματα συστάσεων είναι υποχρησιμοποιημένες όσον αφορά την προσαρμοστικότητα και τον σχεδιασμό μαθημάτων από τον δάσκαλο. Η προτεινόμενη πλατφόρμα χρησιμοποιεί ένα υβριδικό σύστημα συστάσεων στον πυρήνα του συστήματος, το οποίο επιτρέπει στην πλατφόρμα να συνθέσει ένα προσαρμοστικό μοντέλο βασισμένο στο μαθησιακό προφίλ του μαθητή και στους διδακτικούς στόχους που παρέχονται από τον δάσκαλο. Οι δάσκαλοι μπορούν να δημιουργήσουν εκπαιδευτικούς πόρους μέσω της διεπαφής της πλατφόρμας και να παρέχουν αρκετό περιεχόμενο για να χρησιμοποιήσει ο αλγόριθμος συστάσεων προκειμένου να δημιουργήσει το εξατομικευμένο φύλλο εργασίας του μαθητή. Το υλοποιημένο υβριδικό σύστημα συστάσεων κατατάσσει δυναμικά τα μαθησιακά αντικείμενα χρησιμοποιώντας περιεχόμενο και συνεργατική φιλτραρίσματος με βάση πέντε εκπαιδευτικά κριτήρια: VARK (συμβατότητα στυλ μάθησης), αντιστοίχιση δεξιοτήτων 4Cs, προηγούμενη απόδοση μαθητών, απόδοση συνομηλίκων και προτιμήσεις μαθητών. Εφαρμόζοντας έναν αλγόριθμο που χρησιμοποιεί αυτούς τους τύπους κριτηρίων στη διαδικασία σύστασης, βελτιώνει την επιλογή περιεχομένου δημιουργώντας εξατομικευμένες συστάσεις εντός του σκελετού που ορίζεται από τους σκελετούς φύλλων εργασίας που καθορίζονται από τον δάσκαλο, μειώνοντας την χειροκίνητη προσπάθεια που απαιτείται από τις περισσότερες από τις υπάρχουσες πλατφόρμες. Σε αντίθεση με την τρέχουσα μέθοδο δημιουργίας πλατφόρμας, η πλατφόρμα εξαλείφει την ανάγκη για χειροκίνητη παρέμβαση του δασκάλου για κάθε μαθητή και δημιουργεί δυναμικά κάθε φύλλο εργασίας για κάθε μαθητή.

Συνολικά, αναπτύξαμε μια προηγμένη πλατφόρμα με κλιμακωτή αρχιτεκτονική και στόχο να επιδείξουμε μια πλατφόρμα που δίνει στους εκπαιδευτικούς έλεγχο, ενώ παράλληλα παρέχει ένα διανοητικό σύστημα συστάσεων που επιτρέπει στους μαθητές να έχουν μια αποτελεσματική και εξατομικευμένη εμπειρία.

Abstract

Education nowadays has increasingly more classroom diversity that raises the need for personalized learning platforms that support the development of 21st-century skills. Personalized learning is crucial to develop the cognitive and interpersonal abilities that learners require today. The platforms that aim to solve this should support the development of adaptive learning content, tutor designed materialism and provide efficient tools to educators to allow the generation of individualized worksheets associated with certain cognitive levels and educational goals. Educators these days face a lot of challenges on worksheet generation trying to achieve instructional goals for a diverse set of learners profiles. Existing conventional platforms using educational recommendation systems that underutilized in terms of adaptiveness and teacher-driven lesson planning. The proposed platform uses a hybrid recommendation system at the core of the system that allows the platform to synthesize an adaptive model based on the learner's learning profile and the instructional goals provided by the tutor. Tutors can create educational resources through the platform's interface and provide enough content for the recommendation algorithm to use in order to generate the learners personalized worksheet. The implemented hybrid recommendation system dynamically ranks the learning objects using a content based and collaborative filtering based on five educational criteria: VARK (learning-style compatibility), 4Cs skill matching, prior learners performance, peers performance, and learner preferences. By applying an algorithm that uses these types of criteria in the recommendation procedure refines the content selection by creating personalized recommendation within the skeleton defined by the tutor defined worksheet skeletons, reducing the manual effort that is required from most of the existing platforms. Unlike the present platform generating method, the platform eliminates the requirement for the tutor to manually intervene for each student and dynamically creates each worksheet for each student. Overall, we developed a state of the art platform with scalable architecture and the goal of demonstrating a platform that gives educators control while also providing an intellectual recommendation system that allows learners to have an effective and personalized experience.

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Chapter 1 - Introduction

1.1 Problem Statement

The Failure of "One-Size-Fits-All" and Student Disengagement

The majority of the conventional learning platforms use traditional approaches that do not consider the individuality of each learner [1], [2]. Traditionally most platforms adopt an “One-Size-Fits-All” approach that takes into consideration only the tutor input and fails to consider the learner's individual skills, learning, background knowledge, preferences and the educational goals that lead to pedagogically ineffective solutions [2], [3], [4]. All the conventional platforms that follow this type of implementation suffer from issues like high dropout rates and low retention due to high cognitive overload and disorientation when the student must deal with unstructured learning materials or resources that do not match the learning profile of the student [5], [6]. Furthermore, when all students have to face fixed sequences of learning, they often may feel disinterest and dissatisfaction among learners with diverse learning preferences and varying rates of comprehension [3], [5], [7]. The widespread disengagement indicates the need for a perspective change towards a learner-center model approach that can provide an adaptive environment that adapts the content that fires the students’ needs, strengths and preferences of each individual student [2], [4], [8].

Limited Teacher Control and High Manual Workload

An increasing number of existing digital platforms are falling into the same gap when it comes to developing platforms that employ teacher-driven methodologies. The majority of platforms use a sterile approach that results in an automated process that manages the student or the objective of the learning material, such as a worksheet like a "black box," and constructs their systems to automate the learning process or the generation of learning resources [9], [10], [11]. This approach leaves educators without the tools to create individualized learning materials that correspond with particular learning objectives and cognitive levels (such as Bloom's Taxonomy). As a result, platforms that use recommendation systems fall short of offering sufficient resources to assist with the time-consuming and labor-intensive daily manual processes of classifying learners and personalizing the learning materials [12], [13], [14]. This type of labor is an important challenge for any learning environment, and educators find it to tackle. They report that, for large

groups of students from diverse backgrounds, there is a lack of individualized learning resources and assessments that are required to achieve effective learning [15]. Without these tools, it is difficult to identify the learning difficulties and create individualized profiles [13]. Furthermore, tutors are frequently unable to effectively manage all of the students with timely in-person educational sessions since there are no automated technologies that gather the essential data and evaluate it to reduce the risk of supplying materials that do not suit the learner profile in real time. To support everyday classroom instruction, digital learning platforms need to translate existing pedagogical approaches into practical and manageable system functionalities. In many cases, teachers are forced to rely mainly on their own observations to adapt instructional materials, which may not always be sufficient or accurate, especially in classrooms with diverse learner profiles. As a result, there is a clear need for platform-level solutions that reduce the amount of manual preparation required from educators, while still allowing them to maintain control over the pedagogical structure of the learning materials.

Technical Bottlenecks: Cold-Start and Data Sparsity

When a new student enrolls in a class, the teacher does not have any prior information about the student's learning profile and preferences. As a result, educational recommendation systems face the same "cold-start" issue and struggle to make accurate recommendations for new users in the absence of the learners' profile historical data. Each time a new learner joins the platform, a new incident of the data sparsity problem arises [9], [11]. At this time, the platform lacks the behavioral, performance, and instructional material preferences that are necessary for an accurate algorithmic score of the newly registered learner. Moreover, even the students that are already registered in a platform usually do not engage with a large portion of the available learning objects, which is also a data sparsity problem and makes again challenging for the algorithm to reliably calculate a score and forecast preferences or calculate similarities. The lack of occasional recurrent evaluation of the specific resources leads to data sparsity, which destroys the possible relationship between similar learners and generates a "transitive loss" [16].

Another fact that current systems struggle with is that the system has been developed with many static parameters and they do not factor dynamic parameters. For example, some systems may have static parameters like the difficulty of a learning object and fail to capture the learner's progression of knowledge which is a dynamic parameter that reflects the current state of the student

profile. Most traditional algorithmic models neglect to record raw data regarding learner performance on the platform and do not account for dynamic changes surrounding the learner's profile and changes over time. Lack of understanding of the crucial information required for a successful educational process can occasionally result in knowledge overload, which produces recommendations that are noise or irrelevant. In addition to the above information, a crucial problem is the absence of high-quality datasets that will make these technologies reproducible. Researchers find it challenging to evaluate new models proposed by recently formed systems with well-known models due to the lack of high quality trust-worthy datasets.

The Gap in Pedagogical Evaluation

The Research of pedagogical efficacy of the recommendation systems is remarkably lacking even though many systems evaluate their efficiency by assessing technical metrics like precision and prediction accuracy of the models (e.g., MAE or RMSE). Most of the models that have been used in the research field mainly focus only on performance properties and neglecting to employ metrics that more accurately characterize the growth of student learning, such as cognitive development or behavioral transformation [17]. To assess these issues, we need that go beyond the current standards and set goals to impact the long-term academic performance in a range of real-world classroom environments, student engagement, and 21st-century skills (the 4Cs: critical thinking, communication, collaboration, and creativity) .

This thesis addresses the identified challenges from a system design and implementation perspective, focusing on the technical realization of established pedagogical and adaptive learning principles.

1.2 Objectives

Despite the increasing number of digital learning platforms, significant implementation gaps remain, particularly in the integration of adaptive mechanisms within everyday teaching practice. This transformation represents a shift from the traditional platforms to achieve a landscape change to a more student oriented framework where the instructional approach is tailored to each individual learner's needs. Even though the number of digital platforms is growing daily, there are still a lot of gaps in their implementation. The platforms are employing teacher-driven ways to try to reduce manual effort while also providing some pedagogical control. To build a platform that genuinely offers authentic adaptive blended learning environments, this thesis

suggests integrating pedagogical and technological frameworks with a learner-oriented approach. The platform seeks to close the gap between the automations and the already defined instructional guidelines, such as Bloom's Taxonomy and VARK learning styles by utilizing a sophisticated algorithm and real time analytics about the student's current status. The objectives listed below describe a thorough approach that has been used to create the suggested platform.

Individualized Pedagogical Adaptation

The primary goal of platform design is to move from the conventional platforms approach that handles the platforms as an "one-size-fits-all" instructional model solution to a more learner-oriented paradigm that promotes an approach that optimizes supports the learning process of each individual. To achieve a more learner-oriented approach the platform wants to provide personalization shaped around student cognitive levels, preferences and performance making sure that provides a purely individualized and pedagogically grounded approach. With that approach we can reflect changes in the learner's profile over time and avoid any possible frustrations. Additionally, the objective focuses on dynamically modifying worksheets and delivering content-based student's real time behavior and performance. To achieve this the platform incorporates pedagogical frameworks like VARK learning styles and Bloom's Taxonomy, along with recommendation logic that utilizes the behavior, preferences and performance of the learner to support individualized content delivery for each student.

Systematic Development of 21st-Century Skills

In the modern era of education, the instructional process in or out of the classroom should not be a traditional lecturing process but an approach in which the educator acts as a coach. The educator should appear as a mentor that guides the students actively with inquiry-based activities. In order to accomplish this, the platform supports instructional activities aligned with the 4Cs(Critical Thinking, Communication, Collaboration, and Creativity) in a mixed learning environment that makes use of the platform to produce learning materials for every individual student. By utilizing the 4Cs in the blended learning environment, a meaningful environment is created that encourages learners on all platforms to build higher order thinking skills.

Support for Teacher Orchestration and Workload Reduction

These days most of the platforms work as “black box” systems and have automations that are sterilized focusing only on automation and really providing enough tools to the teacher or offloading them from the large amount of workload that they need to overcome. Based on this problematic state of the current platforms, a significant objective is to empower the educators with tools to easily orchestrate the pedagogical process and automations that really reduce the labor intensive and time-consuming procedure they need to follow in order to have individualized and optimized materials for each learner's needs. The educator’s pedagogical control is set to come with the ability to define worksheet templates with real pedagogical frameworks in mind (e.g. VARK, Bloom’s Taxonomy) and leaving the individualization to be handled by the platforms recommendation algorithm that handles dynamic selection and ranking of the learning materials. By automating repetitive administrative duties like resource screening and determining whether a piece of content is appropriate for a particular learner, the platform functions as a system-level support tool for educators. This objective will allow the instructors to have more free time to spend on identifying particular learning deficiencies and offering focused assistance to students that need their assistance.

Cold-Start Mitigation for Early Personalization

A very common problem that most of the platforms struggle with is the “cold-start” problem. The system lacks historical data from the newly registered learners on the platform and can provide accurate recommendations that match either the preferences, performance or the learning profile of the learner. The goal of this objective is to offer a solution that enables the initialization of a newly enrolled learner's baseline profile. By handling the initialization of the baseline profile of the learner we can allow for better initial recommendations that match better the student learning profile and lower the risk of providing learning material that does not match the student strengths and needs.

Optimization of Cognitive Engagement and Knowledge Absorption

Learning is a quite intricate process that can be affected by many factors. This objective aims to maximize the learning process by improving the engagement with proper instructional content in order to support an effective knowledge acquisition. The platform by serving through the recommendation algorithm an automated and intelligent way to filter is designed to help to

reduce the cognitive overload by having a large pool of uncategorized learning material. The objective utilizes the instructional content, the tracking of the performance, engagement and behavior learner factors to capture the evolution of the learner's profile state. Furthermore, the platform updates the learner's profile in real time and allows for immediate impact by personalizing the new learning materials offered and encouraging the student and allowing the students to see their own reflected progress. This ensures that the recommendations are appropriate for the learners' cognitive abilities and that the platform maintains their interest.

Reusable Repository of Pedagogical Methods and Learning Materials

The final objective is to transform the platform into a structured, reusable collection of instructional techniques and educational resources that can support a wide range of long-term curriculum objectives. This objective enables the educators to store, adapt, reuse learning objects and worksheet templates and create a high-quality archive that contains teacher-verified educational materials (e.g. videos, assessments, quizzes) for instructional purposes. This goal facilitates knowledge sharing and sustainable instructional design by encouraging uniformity and reusability. By accumulating pedagogical artifacts, the repository also makes it easier to continuously enhance teaching methods.

1.3 Thesis Structure

The thesis is structured as follows: In chapter 2 Background and Related work describes the theoretical part that supports the development of the platform, such as adaptive learning, blended learning, learning styles etc. and at the same time describes existing state of the art platforms and identifies differences and the research gaps. In chapter 3 System Requirements and Design describes the functional and non-functional requirements of the proposed platform and presents the system architecture, core services and the communication mechanism of the platform. In chapter 4 System implementation outlines the technical resolution of the platform, the selected technologies, frameworks and the implementation of the main components of the platform. In chapter 5 Results describe the outcome of the platform, the delivered functionality of the platform and the perceived educational impact. In final chapter 6, Conclusions and Future Work summarizes the contribution of the proposed platform within the scope of this thesis. It identifies constraints, explores theoretical, practical, and technological ramifications, and suggests future study and system improvement directions.

Chapter 2 - Background and Related Work

2.1 Bloom's Taxonomy Framework

In 1956, Benjamin Bloom, along with a team of psychologists, developed the initial version of Bloom Taxonomy. He proposed this framework to support the systematic classification of cognitive learning objectives. They designed a sequence structure for categorizing cognitive skills; with this sequence, the model reduces the required instructional labor and allows for promoting higher forms of thinking in learners. This initial version has six hierarchical categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation [18], [19], [20].

2.1.1 The Revised Bloom's Taxonomy (RBT)

Many years later, after many changes in education, there was a need for further change. David Krathwohl and a group of collaborators in 2001 attempted to revise the framework. The Revised Bloom's Taxonomy (RBT) shifted the category names to allow better description for the thinking process from nouns to dynamic action verbs. The revised hierarchical categories are the following: Remember, Understand, Apply, Analyze, Evaluate, and Create [18], [20], [21]. The revised version replaced and expanded the original Synthesis category's context. Additionally, this version transformed the framework into a two-dimensional structure comprising the Knowledge Dimension and the Cognitive Process Dimension. The original bloom has since been replaced by the revised bloom, which is now referred to as the default version in the majority of studies [20], [21], [22].

2.1.2 Dimensions of the Cognitive and Knowledge Framework

The six main categories comprise 19 distinct types of psychological processes that make up the Cognitive Process Dimension, which is an ordered hierarchy of increasing cognitive complexity [23]. Based on the scaffolded structure, these categories are divided into two main categories: Higher-Order-Thinking Skills (HOTS), which include the levels of analyzing, evaluating, and creating, and Lower-Order-Thinking Skills (LOTS), which include the levels of remembering, understanding, and applying [18], [19], [24]. The content that must be learned is divided into four different levels by the Knowledge Dimension:

1. **Factual Knowledge:** The fundamental concepts, like terminology and particulars, that students need to understand in order to be familiar with a field [20], [23].

2. **Conceptual Knowledge:** The connections between fundamental components of a broader framework, such as theories, models, and classifications [20], [23].
3. **Procedural Knowledge:** Understanding how to perform a task, including criteria for applying skills, algorithms, and methods of inquiry [20], [23].
4. **Metacognitive Knowledge:** Understanding cognitive tasks in general and being conscious of your own thought processes [22], [23].

2.1.3 Pedagogical Application

Bloom's Taxonomy is still a key resource for lesson preparation, curriculum development, and assessment alignment [18], [20], [25], [26]. It is commonly used by educators to structure learning activities beyond basic rote memory toward the development of higher-order skills [18], [24]. The taxonomy is used to guide learners from Level 1 (memorizing definitions) to Level 6 (developing new diagnostic measures or prognostic indicators) in specialist domains such as clinical surgery [21].[27] Additionally, academics are now automatically classifying learning objectives based on Bloom's levels using machine learning (Naive Bayes, logistic Regression, SVM, etc.) and deep learning models like BERT, providing instructional designers at scale with support [19].

2.2 4Cs

In 2002, with the assistance of the Partnership for 21st Century Skills (P21), through research on the learner abilities students need to succeed in classrooms based on traditional academic contexts, they developed a framework called the 4Cs. The 4Cs is a learning model that emphasizes developing higher-order thinking skills, interpersonal skills, and creative problem-solving abilities that are essential for both personal and professional success and introduces 4 key concepts/components: Critical thinking, Creativity, Communication, and Collaboration [28], [29], [30], [31], [32].

2.2.1 Defining the 4Cs Dimensions

Every element of the 4Cs focuses on a particular social or cognitive area required for students' overall development:

1. **Critical Thinking (C1):** This is a core cognitive skill a student should possess. This particular component requires using logical reasoning to address problems utilizing evidence-based reasoning rather than rational decision-making [31], [32].
2. **Creativity (C2):** The creative component is defined as the capacity to enable students to investigate novel ways of thinking and to approach each situation from several perspectives in order to identify novel approaches. This component allows the student to come up with unique and creative ideas that they can utilize to be creative [29], [30], [32].
3. **Communication (C3):** In the education setting that requires exchanging knowledge in both digital (both verbal and nonverbal) and traditional classroom settings, being able to share, access, and analyze information is an important skill. The ability to manage communication overload is an essential talent, particularly today when learning is increasingly digital [26], [29], [30], [32].
4. **Collaboration (C4):** The dedication to appreciating different viewpoints while working expertly as a team to accomplish shared objectives. It emphasizes internalizing communal principles, adaptability, and shared responsibility [29], [30], [32].

2.2.2 Pedagogical Integration via Student-Centered Models

In the modern era of education, literature describes a transition away from the traditional teacher-led instructional model that focuses solely on memorization towards a learner-oriented model that considers each learner's unique profile [30]. The development of the 4Cs is commonly associated with learner-centered instructional models. In a modern classroom, a learning technique fosters the 4Cs. A very common technique is the Project-Based-Learning (PBL). With the use of PBL, the learning process can foster skills and enable students to collaborate and focus their learning on real-life problems or their interests [30]. The tutors in these types of environments move away from the traditional teacher who is just a transmitter of knowledge towards a coach who helps students based on their needs and provides a clear, structured path towards the correct skill set [33]. Furthermore, research indicates that, in addition to project-based learning, other model integrations, such as gamification and problem-based learning, have demonstrated favorable outcomes for learners' motivation and engagement with the competencies [31], [33], [34].

2.2.3 Synergy Between the 4Cs and Bloom's Taxonomy

The 4Cs learning model and Bloom's taxonomy framework intersect in the Higher-Order Thinking skills. Comparing them reveals that "Analyze," "Evaluate," and "Create" are Revised Bloom's Taxonomy levels that are strongly related to "Critical Thinking" and "Creativity" [18], [26], [29], [35]. This correlation is explained by the researchers who developed both frameworks, which emphasizes the importance of developing skills associated with higher cognitive levels. They want the learners to follow a curriculum with proper assessment that targets these levels and has the required clinical and professional reasoning. These skills are required for the learner to evolve beyond simple fact recall to the use of the upper-level skills, especially in complex sciences like physics or medicine. For these reasons, the Bloom Center activities have been designed to always develop the 4Cs simultaneously to help them achieve the required level of expertise [21], [31], [36], [37].

2.2.4 Challenges and Contextual Barriers

Every framework or technique that has been used in education apart from the positive results that have when we apply them as expected, usually the integration faces a lot of challenges and barriers [29], [30]. Large class sizes, a lack of digital infrastructure, and an emphasis on linguistic knowledge are the most frequent issues over communicative competence that have been noted in the use of the 4Cs in education, according to the researchers [29], [30]. Furthermore, a common obstacle is a theoretical knowledge gap or a lack of expertise in the theory and practice of pedagogical abilities, which may prevent teachers from creating instructional materials and processes that are up to date with 21st-century competencies [38].“Additionally, the literature indicates that a variety of contextual factors may influence the effectiveness of different skill development approaches.”. For instance, the location of the school is a very important factor. Students who attend schools in urban areas may have more dominant communication skills because they have better access to technology, whereas students who attend schools in rural areas may have higher collaboration skills because of cultural norms of mutual assistance [28].

2.3 Blended learning

Blended learning is a pedagogical model that is widely used in modern education classrooms of the 21st century. In many situations, the blended learning model is described as a hybrid model that creates a new model which combining traditional face-to-face instruction with

digital learning experiences [39], [40], [41]. According to the model definition, it is a learning that partially incorporates online learning and at the same time offers some “kind of control over the time, place, and pace of their learning” [40], [42]. Unlike plain online learning, blended learning demands careful planning and organization to bring together the physical and virtual environments, aiming to create a cohesive learning environment and learning path for the learner [43], [44]. An increasing number of esteemed institutions are adopting this hybrid approach to maximize learning outcomes by leveraging the benefits of both digital and physical learning processes and removing any obstacles that might arise from using the individual learning process as it is [39], [41], [45].

2.3.1 Theoretical and Pedagogical Frameworks

This pedagogical model design represents a grounded approach that is established based on cognitive educational theories. The Revised Bloom's Taxonomy, which offers a six-level classification for the learning objectives, is commonly used as a reference framework in blended learning designs. The goal using this framework is to guide the learners from low-order skills (such as applying, remembering, and understanding) to high-order skills (such as analyzing, evaluating, and creating) [41], [44]. These days, in many modern implementations, we encounter the use of the 4Cs model, which emphasizes cognitive abilities, including Critical Thinking, Communication, Collaboration, and Creativity. Within this approach, the 4Cs are often addressed through activities targeting higher-order cognitive skills.

Moreover, the model is structured around a student-oriented framework reliant on constructive alignment, aiming to enhance efficacy and ensure the model fulfills the objectives of the educational process. Additionally, efficient educational exercises and evaluations are all methodically incorporated into the model's design [40], [46]. A fundamental component of the strategy is the capacity for personalization grounded in pedagogical theories, typically by employing frameworks such as the VARK learning style. The VARK learning style employs a distinct categorization method centered on learners' sensory preferences, covering four primary categories: Visual, Auditory, Read/Write, and Kinesthetic [39]. The current study indicates that popular advice among researchers is to integrate these preferences to support student engagement and academic outcomes in a blended learning environment [40], [42], [44].

2.3.2 Implementation Models

Blended learning is a pedagogical approach that has been widely employed in the 21st century and has been investigated by several researchers for its effectiveness and its impact on learners. Over the years, we have been able to execute the blended learning model in several ways using pre-planned models that establish the ratio of virtual to in-person components:

1. **The Rotation Models:** This learning model method adopts a teacher-centered approach, wherein the instructor maintains at least one online station (a specific, designated learning modality or activity) and either maintains a set rotation schedule or modifies it between pedagogical process modalities [40]. There are four subcategories within this particular model:
    a. **Station Rotation:** In this sub-model, the students are divided into smaller groups, each of which has a station in a single classroom. Throughout the entire learning process, at least one segment of the lessons will involve the use of digital devices [40], [41].
    b. **Lab Rotation:** This model takes a similar approach to the Station Rotation, but in order for the students to complete the online segments, they must use the lab's dedicated computer, which allows them to use the specialized software needed for the particular lesson segment [40], [41].
    c. **Flipped Classroom:** This sub-model adopts a novel strategy and flips the normal classroom instruction sequence. In a regular classroom, the teacher guides the learning process; however, in this instance, the students participate in the learning process independently at home, through video lectures, and in the classroom, they undertake the position of the instructor. This reversed approach encourages active learning, guided practice, collaboration, and problem solving [39], [41], [42], [44].
    d. **Individual Rotation:** This strategy adopts a focus on the individual learner, as opposed to group-based strategies. Each student has a personalized schedule, and following a different path emphasizes the individual learner's needs and interests [40], [41], [42].
2. **The Flex model**: Online learning is a fundamental component of this model. All learners follow the same schedule, mainly through a digital educational platform, while

having the ability to contact the lesson instructor in person in small groups or for a private meeting, independent of the rest of the students [40], [42]. This type of model is suitable mainly in cases where physical appearance is a barrier to the learning process and remote learning is required alongside a fluid and not rigid schedule [40].

3. **The A La Carte Model**: This model offers a blended approach, allowing students to choose some courses entirely online and others in person. At the same time, the learner has always had the option of one-on-one instruction with the instructor, either in person or online. This model allows the learner to personalize their learning experience without requiring someone to blend the courses for them [40], [42].
4. **Enriched Virtual Model**: The online learning strategy lives in the core of this model. The student mainly follows the course through an online setting and has several face-to-face sessions with the teacher to solve any doubts and help them understand the course concepts [40], [41].
5. **Project-Based Blended learning**: This specialized model integrates online and face-to-face learning to enhance learners' practices and processes [40]. It encourages students to work on real-world projects and develop career-relevant skills. Research indicates that this model is particularly effective for complex scenarios, such as foreign language acquisition or real-world challenges like IoT automation engineering, where practical application is essential [40].

2.3.3 Technological Infrastructure and Impact

Empirical research shows that Blended Learning has been associated with positive outcomes on students in many ways. Research shows that learners who participated in blended learning sessions have a largely positive impact on academic performance, learning autonomy, and their overall satisfaction [39], [40], [47]. Additionally, learners show signs of improvement in engagement and passing rates compared to traditional learning techniques [40], [41]. Many trends are happening in the educational space, and some of the state-of-the-art learning designs that have been used for blended learning are microlearning and modular learning, which break down the learning process into small, more manageable units of content that will help the learning to match today's fast-paced learning needs [48].

The modern implementations of Blended Learning is bonded with the use of Learning Management Systems (LMS). Most of the modern implementations are using platforms such as Blackboard and Moodle to help content delivering and track the learners progress [40], [49]. Furthermore, with the large impact that COVID-19 pandemic had on the world, we show an acceleration on the need for blended learning environments and large digital transformation in many aspects of education. These days Blended learning is widely adopted, particularly in higher education [40], [41], [48]. Shifting towards this learning model enabled us to overcome some very important barriers in modern education like distance or overcrowded classrooms while keeping the cost down and making the assignments multi-delivery and grading [40], [41].

2.3.4 Emerging Trends

With the current state of the art, the literature reports increasing focus towards data collection, reinforced feedback, and recommendations. Many blended learning implementations today aim to personalize the learning experience for each learner through Learning analytics and Educational Data mining [17]. By using these practices, the instructor has a clear picture of the learner profile, enabling them to provide individualized, actionable feedback that will be much more effective for the learner's growth. Moreover, many higher education platforms use tools that leverage Artificial intelligence and collaborative/hybrid recommendation algorithms to recommend learning materials suitable for each individual learner's needs, preferences, cognitive level, or preferred learning profile [47], [50]. At the same time, this type of system enhances blended learning by offloading chores from the instructor and allowing them to support syllabus planning and have an effective learning process. Through the blended learning model, some emerging technologies are born and extend learning environments through emerging technologies such as the Internet of Things (IoT) and Mixed Reality (MR/AR/VR), thereby bridging the gap between theoretical knowledge and practical application [40], [48].

2.4 Adaptive Learning

Education, as it evolves over the years, changes many aspects of the educational process. Due to the modern-day need for specialized learning that requires a quite high level of knowledge in a short amount of time, education strives to fulfill this need. A quite successful approach in the modern education era is the mode of adaptive learning. Adaptive learning is a solution that was proposed at first with the goal to transition from the classic learning model that used to have a one-

size-fits-all approach without having any consideration in mind for the needs and preferences of each individual. This model transitions from traditional teaching to a data-driven, technology-grounded instructional approach tailored to deliver an experience designed for each individual's unique learning profile [4], [51], [52]. As Weir says in his 2021 research on Comparative Review on adaptive learning platforms, the adaptive learning implementation these days is divided into three versions of adaptive learning. According to him, version 1.0 is the most basic adaptive learning system, which uses a decision tree to personalize based on predefined pre-assessment results. In version 2.0, we meet implementations that use simple algorithms to automate some parts of the process, but without improving the system performance over time. The last version of adaptive learning is 3.0, which characterizes and recommends, often with algorithmic implementations that utilize Artificial Intelligence (AI) or Machine Learning (ML), and is usually improvable and scalable over time, and technically simulates some part of the tutoring process [4], [52], [53]. Generally, we see a shift in the educational landscape toward adaptive and intelligent models that have the goal to provide high-quality and inclusive education material that is personalized to each learner profile in a scalable manner [53], [54], [55].

2.4.1 Theoretical and Pedagogical Background

A fundamental principle of the adaptive learning framework is Mastery Learning, a concept developed by Benjamin Bloom that holds that every student should have a structured scaffolding process and should only advance to more complex units if the learner demonstrates the necessary competence [56], [57], [58]. Revised Bloom's Taxonomy is the foundation of the framework's instructional design, which enables the activities to be structured from low-order to high-order thinking [56], [59], [60]. Additionally, adaptive learning is a learner-centered framework in which educators offer tailored experiences, such as customized learning resources, timely tailored feedback, and instructions. Through this method, the framework offers a dynamic scaffold tailored to each learner's skill level and ensures it aligns with their preferences to avoid overwhelming or disengaging them [61], [62]. Recent research on dynamic learning models that force learners to continuously manage their cognitive and emotional states shifts the perspective away from conventional static learning models. Many researchers highlight this in the application of Self-Regulated Learning (SRL) in adaptive learning. These studies concentrate on integrating the four pillars of the CAMM framework cognition, emotion, motivation, and metacognition which serve

as the foundation for the scaffolding system that enables students to take charge of their own learning [63], [64].

2.4.2 Implementation methods

Adaptive learning is a framework designed with a functional architecture that aims to move away from traditional one-size-fits-all instruction models to a student-oriented model that tailors the educational progress towards the needs of each individual learner [56], [58]. Generally, this architecture consists of three fundamental parts that control pedagogical knowledge and accelerate the process of personalization:

1. **The learner Model**: The learner's profile update lies at the heart of this model's closed-loop methodology. This supports a dynamic system that gathers information on behavioral, emotional, cognitive, and demographic traits [56], [57]. By gathering these indicators, learners' development is made dynamic, and their present knowledge status may be accurately determined in real time [55], [56].
2. **The Domain Model**: This model outlines the cognitive linkages, or knowledge graphs, that connect the subject matter to discrete learning objects (LOs), such as exercises, quizzes, and lessons [56]. It offers an organized hierarchy of educational materials aligned with specific learning objectives [56], [57].
3. **The Adaptation Model**: The "core engine" of the entire system. This section uses each learner's unique learning profile information from the learner model [56]. A recommender system that chooses the best resource for the student will receive the data. Generally, create an adaptivity loop that enables the selection of the subsequent resource and reacts dynamically to any alteration in activity behavior [56].

Many researchers employ implementation strategies that dictate how and when the environment adapts to the learner to apply and operationalize all these components:

1. **Macro-Adaptive**: This approach entails the pre-planned modification of a thorough curriculum or instructional design to accommodate various learner cohorts [27], [65]. Adaptations are usually predicated on relatively consistent student prerequisites, including prior knowledge, wherein distinct groups receive foundational support or diverse instructional activity sequences [27], [61], [65].

2. **Micro-Adaptive**: This approach reacts to the learner's particular actions, feedback, and performance during a task. It is characterized by real-time, "in-the-moment" modifications [61], [65]. To help students overcome particular challenges as they arise, it uses sophisticated algorithms to deliver real-time educational support, such as adaptive hints or instantaneous corrective feedback [61], [65].
3. **Aptitude-Treatment Interaction**: This method focuses on how certain instructional interventions interact with a learner's innate skills, such as visual or auditory inclinations [65]. It seeks to carefully match students with instructional strategies that maximize effectiveness in accordance with their individual cognitive and learning preferences [65].

In addition to the strategies mentioned, many researchers use frameworks such as the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to align learning objects with system functionality [4], [53]. Additionally. Many other systems used evolved frameworks, such as the 4C/ID framework, to enable complex problem-solving by dynamically adjusting task complexity and eliminating scaffolding [4], [53].

2.4.3 Technological Infrastructure/background and impact

In adaptive learning, we see a wide range of approaches and technical solutions. At the core of the computational real-time personalization prediction model, we often use algorithms such as Bayesian Networks and Probabilistic Graphical models to manage learners' knowledge levels and dynamically update learners' levels of expertise [57], [66], [67]. Moreover, in recommender systems that facilitate suggestions based on learners' interactions with educational content, we observe the application of methodologies such as Singular Value Decomposition (SVD) and Collaborative Filtering (CF) [66], [68]. In some advanced implementations that process data collected sequentially to predict academic outcomes based on learning patterns, systems use Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTMs) [56], [69]. Most algorithms that leverage data to manage or predict use Educational Data Mining to develop the learning model and collect data such as demographics, cognitive, and behavioral attributes [56], [57].

The application of the adaptive learning framework through these technologies has shown us some significant impact on the educational process. We have encountered significant improvement in academic performance, learner engagement, and learning efficacy [4], [56], [68]. As some

empirical studies indicate, in most of the research we had to compare adaptive learning with traditional learning techniques, learner-oriented adaptive learning outperforms teacher-led traditional models, particularly in complex subjects like mathematics and science [56], [58]. By dynamically adjusting content difficulty and tempo, these systems efficiently address Benjamin Bloom's 2-sigma problem, enabling group-taught students to achieve learning gains comparable to those from one-on-one human tutoring [56], [58]. Moreover, adaptive learning functions as an essential instrument for fostering educational inclusion, exhibiting significant effectiveness in reducing success disparities for kids with unique educational needs, including those with ADHD, dyslexia, and autism [64], [70]. Longitudinal evidence indicates that the constant feedback mechanisms fundamental to these platforms promote self-regulated learning (SRL) and enhance long-term information retention [4], [64].

2.4.4 Trends/State of the art

There are numerous approaches to implementing a new educational framework, such as the adaptive learning framework, in the modern era of education. By examining the state of the art today, we can capture the most advanced solutions that leverage numerous integrations, such as instructional frameworks, generative models, and multimodal biometrics. The present state of subjects can be divided into the following categories:

1. **Integration of Generative AI and Large Language Models (LLMs)**: Numerous adaptive learning implementations are transitioning from standard machine learning and rule-based approaches to generative AI. These implementations leverage the capabilities of LLMs, such as OpenAI GPT-4, to enable a highly customized, content-aware learner profile, including learners' age, prior knowledge, and performance history [51], [56].
2. **Neuroadaptive Training and Multimodal Data**: In a highly demanding educational field, many researchers have sought to incorporate advanced systems to detect cognitive struggles or disengagement and enable timely decisions that optimize learning process efficiency. In that case, researchers used physiological sensors such as Electrocardiography (EEG) and Near Infrared Spectroscopy (fNIRS), and eye tracking, which enable tracking of the learner's cognitive state at any time while wearing these sensors [4], [56], [63], [71].

3. **Advanced Recommendation and Pathfinding Algorithms**: Many implementations that combine deep learning models with collaborative filtering to generate more sophisticated, reliable algorithms often use hybrid AI models. These systems employ an ontology model to address a crucial challenge faced by most educational platforms: the "cold-start" problem, which arises from the lack of prior learning profile data. Additionally, they can handle the difficulty as a variable attribute that varies in real time based on the learner's learning profile state by employing a pathfinding algorithm [55], [66], [68].
4. **Evolved Instructional Design Frameworks**: Lastly, the sources offer updated approaches to adaptive teaching in real-world classroom settings. This incorporates the LoGeT (Localize-Generalize-Transfer) structure, which guarantees the generalizability of adaptive interventions across different grades and subjects. The advanced 4C/ID model, which incorporates Learning Analytics (LA) to enable complex problem-solving by dynamically modifying tasks and scaffolds based on the learner's changing performance, is another example of state-of-the-art [27], [61], [72].

2.5 Educational Recommender Systems

By selecting appropriate learning artifacts from vast digital libraries, Educational Recommender Systems (ERS) are advanced information filtering frameworks designed to reduce the problem of information overload [1], [2], [73], [74]. In contrast to general-purpose recommenders, ERS are designed to support learning by customizing learning routes, evaluations, and content to each student's specific pedagogical needs [75], [76], [77]. This signifies a substantial change from the conventional "One-Size-Fits-All" teaching paradigm to a learner-centered model that adapts in real-time to each student's unique cognitive talents and learning preferences [1], [8], [78].

2.5.1 Architectural Foundations and Filtering Methodologies

Student profiling, material collecting and processing, and a suggestion generator are the three main components of a functional ERS [38]. Three main filtering paradigms are typically used to assess these systems' efficacy:

- **Collaborative Filtering (CF):** Based on the interactions and preferences of peers who share similar interests, this approach is the most widely used to forecast a learner's

interest [74], [79]. Although CF is good at revealing serendipitous content, it often has issues with data sparsity and the "cold-start" problem, which prevents it from making precise recommendations for new users or products without previous interaction data [40], [73], [80].

- **Content-Based Filtering (CBF):** By examining item attributes and descriptions, this method suggests products that are similar to those a consumer has previously favored [74], [79]. But CBF frequently results in overspecialization, limiting students to a small number of well-known subjects and preventing them from being exposed to new academic fields [10], [79].
- **Knowledge-Based Systems**: To assist students, these systems make use of semantic structures (such as ontologies) and domain-specific knowledge [14], [47]. Because they may make quick recommendations based on initial student profiles or established educational standards rather than behavioral history, they are especially useful for addressing the cold-start problem [47].

In order to eliminate specific algorithmic shortcomings and aim to align suggestions with both technical precision and instructional aims, current research reveals an ongoing trend toward hybrid approaches [10], [73], [78], [81].

2.5.2 Advanced Computational Intelligence and Deep Learning

Educational Recommendation Systems have moved from static content distribution to dynamic, real-time adaptation through the integration of Artificial Intelligence (AI) and Deep Learning (DL) [2], [10], [82], [83]. Specialized neural networks are used by contemporary architectures to handle complicated educational data:

- **Convolutional Neural Networks (CNNs):** These are used to find patterns in visual learning behaviors and automatically extract features from multimedia content [2], [73], [82].
- **Recurrent Neural Networks (RNNs) and LSTMs:** By tracking how a student's knowledge state changes over time and forecasting the next most productive learning task based on their interaction history, these "memory-aware" models are used to suggest sequential paths [2], [11], [13], [80].

- **Reinforcement Learning (RL):** RL agents treat the learning process as a series of decisions aimed at optimizing decision-making policies based on long-term interaction signals, while minimizing frustration and disengagement [14], [80], [82].
- **Graph Neural Networks (GNNs):** These models complex user-item-concept relationships, enabling the system to understand the high-order structural information within a knowledge graph [11], [13].

Precision Education (PE), which enables early identification of "at-risk" learners and the provision of prompt, automated remedial treatments, is made possible by these cutting-edge technologies [13], [74], [78], [84].

2.5.3 Pedagogical Integration and the "Black Box" Challenge

Many well-established learning frameworks have been incorporated in modern Educational Recommendation Systems for the recommendation logic and to maintain instructional severity. Bloom's Taxonomy to ensure cognitive complexity and the VARK model to match content format with sensory preferences are crucial components [27], [85]. The operationalization of the Zone of Proximal Development (ZPD) is a crucial theoretical application; algorithms can suggest tasks that are sufficiently tough to promote growth without producing dissatisfaction by setting student ability and item difficulty on a uniform scale [4], [85].

The "black box" aspect of complicated AI models continues to be a major obstacle to teacher acceptance, regardless of these developments. This has led to an increasing focus on scrutability and Explainable AI (XAI), which guarantees that instructors and students can comprehend the reasoning behind a suggestion [11], [13], [47], [86]. By providing transparent feedback through customizing the learning materials, the system can provide decision support to educators in order to support Pedagogical control and at the same time to lower the instructors' manual labor [17], [83].

2.5.4 State-of-the-art

A clear move toward Precision Education (PE) and student-centered teaching approaches that use real-time data to deliver tailored feedback characterizes the current state of cutting-edge educational platforms [4], [13], [17]. The Taiwan Adaptive Learning Platform (TALP), a comprehensive system created by the Ministry of Education to identify learning impairments and provide individualized resources across the Chinese, English, math, and science curricula, is a

notable example of this [13]. Teachers and students can trace learning paths and fill in historical knowledge gaps in a methodical way thanks to this platform's integration of a knowledge star map and a unique intelligent diagnosis system [13]. Similar success has been shown in higher education settings by well-known commercial platforms like ALEKS, Knewton, and CogBooks, which have been reported to improve pass rates in challenging courses like mathematics by evaluating individual student data to deliver tailored suggestions [4], [13], [27].

To increase student involvement in blended learning settings, other advanced systems emphasize gamification and active learning [87]. For instance, the Quizizz platform has an Adaptive Question Bank mode that dynamically modifies task difficulty in real-time, decreasing language anxiety and adhering to educational principles of practicality and reliability [87]. While the Carnegie Learning platform employs AI to provide customized tasks based on individual student vulnerabilities, DreamBox Learning monitors student interactions in K–12 settings to identify "at-risk" behaviors and adapts task selection based on learner progress [4], [88]. Smart Sparrow uses virtual slides to deliver customized histology courses for specialized fields. Incorrect answers result in instant feedback that points students to pertinent textbook references [7], [88].

Research-oriented architectures are further advancing the use of cognitive and semantic modeling to optimize learning pathways [5], [7]. The Adaptive Learning Cognitive Map Recommendation System (ALCMRS) visualizes a student's cognitive state through subject knowledge graphs, enabling the continuous adjustment of learning partners and activities based on peer similarity [5]. In the domain of computer science, the Protus system (and its semantic-web-based successor Protus 2.0) automatically adapts to a learner's interests by identifying patterns in their learning habits [76]. Furthermore, the IBOX platform has become a vital resource for secondary schools, using online simulations and audio-visual materials to promote self-directed learning and increase classroom productivity [89].

Lastly, by including intelligent plug-ins and analytics dashboards, classic Learning Management Systems (LMS) like Moodle, Blackboard, and Google Classroom are gradually evolving from simple document stores into adaptable environments [38], [40]. These platforms now facilitate mobile-based blended learning, offering students automated progress tracking and round-the-clock connectivity to enhance self-regulated learning [17], [40]. Virtual programming spaces, such as Node-RED, are being used in technical contexts to provide "flow-based" active learning, which enables students to grasp intricate ideas like IoT analytics without requiring actual

hardware [40]. Together, these developments indicate a shift in perspective in which technology serves as an "intelligent teaching assistant," allowing teachers to concentrate on mentoring and critical thinking while the systems handle the demanding task of curriculum customization [2], [84].

2.6 Worksheet and Learning Object Personalization

Learning materials can be tailored to each person's specific needs in order to make the shift from traditional, standardized instruction to a student-centered paradigm [90]. In this regard, the goal of Personalized Learning (PL) is to identify various kinds of student characteristics and employ adaptive technology to help learners' complete appropriate activities [91]. The shift from a "one-size-fits-all" approach to Personalized Adaptive Learning (PAL), in which the learning stage and the teaching strategy are dynamically modified in real-time, is crucial to this evolution [67], [90]. The architectural and pedagogical frameworks for customizing educational resources are examined in this part, with a focus on the use of Learning Objects (LOs) and teacher-driven worksheet templates [55].

2.6.1 Foundations of Learning Objects and Curricular Skeletons

Learning Objects (LOs) are reusable, internet-deliverable educational components that facilitate human knowledge acquisition in contemporary adaptive systems. LOs are usually represented using metadata standards like IEEE LOM, which classifies them by structure, format, interactivity level, and difficulty in order to guarantee their efficient retrieval and reusability. Advanced systems further differentiate between Evaluative Learning Objects (LOev), which are intended to gauge a student's present comprehension, and Expository Learning Objects (LOex), which offer descriptive content [55].

The usage of worksheet skeletons, which educators encourage, is a major development in this field [2]. Several recent approaches incorporate personalization into teacher-defined templates, in contrast to traditional systems that depend on predetermined material sequencing. While the system selects and ranks tasks to meet particular instructional goals, this design guarantees that educators maintain pedagogical control. Using these skeletons, every student receives a worksheet within a common teaching framework that is customized to their cognitive stage and preferences [2], [55].

2.6.2 Multi-Criteria Pedagogical Alignment

The personalization of these materials is driven by mapping student profiles to established pedagogical frameworks, most notably Bloom's Taxonomy and the VARK learning styles model:

• **Cognitive Advancement**: Each object is labeled according to Bloom's dimensions (remember, understand, apply, analyze, evaluate, and create) to ensure that the difficulty of the task matches the student's current cognitive capacity [27], [55], [90].

• **Sensory Preferences**: By determining whether a learner prefers Visual, Audio, Reading, or Kinesthetic input, the VARK profile enables the system to suggest resources that complement their sensory strengths [27], [55], [90].

• **21st-Century Competencies**: To support that technical implementation promotes holistic skill development rather than simply rote memorization, learning tasks are also chosen based on their alignment with the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity) [27], [55], [90].

The platform uses initial questionnaires to create a strong baseline profile in order to address the "cold-start" issue for new users, enabling instantaneous personalized recommendations prior to the availability of past performance data [27], [55].

2.6.3 Correction Mechanisms and Pedagogical Alignment

To operationalize Personalized Adaptive Learning (PAL) in worksheet design, algorithmic selection, and well-established instructional theories, most notably the Zone of Proximal Development (ZPD) must be well aligned [85]. Effective personalization systems, in contrast to conventional "one-size-fits-all" methods, use adaptive testing technology to place student ability and item difficulty on a consistent scale, aiming to keep suggested tasks are sufficiently difficult to promote cognitive growth without causing frustration [85]. Teacher-defined worksheet skeletons, which give teachers pedagogical control over the instructional structure while the system manages the dynamic selection and ranking of particular tasks based on the learner's current cognitive stage and sensory preferences, are increasingly facilitating this process [85].

Modern frameworks use sophisticated knowledge tracking models, including Learning Process-consistent Knowledge Tracing (LPKT) [68], to preserve the accuracy of these personalizations. By taking into consideration individual learning progress speeds, knowledge forgetting mechanisms (based on the Ebbinghaus curve), and knowledge acquisition gains, these

models replicate the dynamic evolution of a learner's state [68]. The system may more successfully translate learning encounters into accurate updates of the student's profile by identifying each student's distinct progress rate [68]. This ensures that the following material recommendations stay contextually relevant.

Additionally, incorporating formative remediation loops is a crucial intervention technique to overcome learning gaps immediately [17]. Intelligent diagnosis algorithms and knowledge star maps are used by sophisticated platforms like the Taiwan Adaptive Learning Platform (TALP) to find the "root cause" of misconceptions, which are frequently traced back to required concepts from earlier grades [13]. When a learning deficit is identified, the system provides tailored remedial materials (e.g., specialized explanatory texts, video tutorials, or diagnostic exercises) and actionable feedback to help the learner master the material before moving on to more difficult subjects [7], [17]. This "closed-loop" architecture successfully turns the system into an intelligent teaching assistant, relieving instructors of the manual planning burden while encouraging students' academic resilience and self-regulated learning [2], [17], [89].

2.6.4 State-of-the-art

The distribution of static content has given way to the dynamic personalization of Learning Objects (LOs) and the automation of customized worksheets in the current state of cutting-edge educational technology. Modern adaptive platforms incorporate personalization into teacher-defined worksheet templates or skeletons, whereas traditional systems rely on fixed content sequencing. This preserves pedagogical control while greatly reducing the labor-intensive manual effort required to design materials for heterogeneous classrooms. Within a common educational framework, these systems provide task-level personalization, assuring that every student receives a worksheet personalized to their unique cognitive stage and sensory preferences (e.g., VARK learning styles). By dynamically ranking and choosing tasks that correspond with personal development objectives, this method enables personalized instruction and the methodical development of 21st-century skills (the 4Cs) [27].

Well-known large-scale implementations, like the Taiwan Adaptive Learning Platform (TALP), use knowledge star maps and intelligent diagnosis systems to pinpoint specific learning gaps and offer prompt, individualized remedial materials in core subjects like science and math [13]. Platforms such as Smart Sparrow, which use interactive simulations and virtual microscopes

to deliver adaptive tutorials in higher education, provide instant feedback that directs learners to specific textbook references or explanatory text for incorrect responses [7]. To keep students from becoming bored or frustrated, formative assessment products such as Quizizz have created Adaptive Question Bank modes that dynamically modify task difficulty in real-time [27], [87].

Advanced research-oriented frameworks have further pushed the boundaries of content generation through computational intelligence. For instance, the Thoth Lab framework provides personalized learning for hands-on computer science projects [90], while the LearnFit system applies machine learning to select and sequence learning objects based on identified learning styles [2], [13]. The MACE system functions as an artificial conversational entity in the context of mobile learning to adapt domain knowledge and offer tailored guidance [38]. Furthermore, using subject knowledge graphs to view a student's cognitive state, the Adaptive Learning Cognitive Map Recommendation System (ALCMRS) enables ongoing modification of learning activities and materials based on peer similarity and knowledge structure [5]. When taken as a whole, these solutions reflect an increasing trend toward a "coaching paradigm," in which technology can support teaching workflow that handles the challenges of curriculum personalization, freeing up teachers to concentrate on mentoring and high-level student involvement [27], [84].

Chapter 3 - System Requirements

3.1 Stakeholders and User Roles

The platform serves as an environment for learners and instructors, enabling them to engage with it for a better experience. This environment hosts a diverse ecosystem of stakeholders with distinct interactions inside the platform and the ability to set or achieve pedagogical goals:

Learners

The Learners stakeholder is at the heart of the platform. The platform offers a learner-centered approach and aims to promote self-regulated learning by enabling learners to interact with it through a personalized learning path.

When a learner uses the platform and interacts with the system constantly, particularly by completing worksheets and rating their experiences, they give vital behavioral and performance data over time. These data shape the learner's learning profile by reflecting their cognitive level, engagement habits, and learning preferences, as well as enabling the platform's dynamic features. The platform uses the data to give an adaptive learning concept, adjusting the generated worksheets and increasing learning competency and motivation.

Furthermore, students benefit from a mixed learning environment in which digital activities supplement in-person education. This integration promotes flexible learning and autonomy, allowing students to advance at their own pace while being aligned with instructional goals.

Teachers

As the mentor and coordinator of each course, the instructor plays a critical role in the platform. The role of the instructor is a vital part of the learning process, and the platform does not seek to replace the role with automations; rather, it uses the instructors as the orchestrators.

The teachers use the learning data available on the platform to educate themselves and build new skills essential to the platform. At the same time, the platform provides teachers with learners' learning profiles, which are essential tools for understanding students’ strengths and limitations and for designing future skeletons, equipping them with the information needed to achieve the instructional goals. Moreover, having humans in the loop is essential for maintaining confidence and ensuring they have a reliable tool that does not supplant them, while allowing them to exercise judgment over the learning process and enhance it with adaptive learning mechanisms.

Educational experts

Educational experts are responsible for incorporating pedagogical knowledge into the platform. Their responsibilities include developing instructional frameworks, curating high-quality learning content, and assuring compliance with accepted educational theories.

They help to structure learning objects by linking them with metadata such as cognitive levels (e.g., Bloom's Taxonomy), targeted abilities (e.g., the four Cs), and instructional methodologies. This organized representation allows the system to provide useful and pedagogically sound recommendations. Furthermore, Educational experts help improve the platform by introducing new approaches, refining adaptation criteria, and assessing the pedagogical effectiveness of learning materials. Their contributions ensure that the platform remains relevant to current educational practices and research findings.

System administrators

The System administrator is a critical role on any platform that contains user-generated content. This role is responsible for managing platform users and ensuring that platform content complies with the platform's data privacy and security standards. Having a platform that allows many users to create content that is generated and provided by each user who has the ability to create, such as teachers, educational experts, and content creators, necessitates content monitoring and evaluation to ensure that the content meets platform standards. The administrator's primary purpose is to provide a secure and consistent learning environment without enabling any user to disrupt the learner's experience.

Content creator

A diverse adaptive platform, like the proposed platform, to be a useful and helpful tool for the instructors and learners, needs to have a large, high-quality archive of learning objects. The Content Creator is an essential role in achieving the goal of creating and expanding the platform's learning objects archive. These stakeholders need to leverage their pedagogical knowledge of cognitive levels, target abilities, and learning methodologies to optimize the creation of the learning object. The creator must use the knowledge to gather all metadata required to build a learning object and then create a reusable learning object that targets specific learning profiles defined by the learning object's metadata. Their contributions increase the variety and quality of available learning tools, which benefit both teachers and students.

3.2 System Requirements

The system requirements for the proposed adaptive blended learning platform can be categorized into functional requirements, detailing the services the platform must deliver, and non-functional requirements, outlining the quality attributes governing the operation of these services, based on the pedagogical objectives, architectural design, and user roles established in the conceptual and technical framework.

Table 3.1. List of requirements

No.	Title	Type	Category
1	Support for Distinct user Roles	Functional	User and Role Management
2	Role based Access Control	Functional	
3	Administrative Management	Functional	
4	Initial Learner Profile Creation	Functional	Learner Profiling and Adaptation Setup
5	Collection of Learner Information	Functional	
6	Dynamic Profile Update	Functional	
7	Storage Adaptive Learner Data	Functional	
8	Learning Subject Management	Functional	Curriculum, Learning Content, and Pedagogical Resource Management
9	Hierarchical Curriculum Representation	Functional	
10	Support Digital and Non-Digital Tools	Functional	
11	Learning Object Metadata Management	Functional	
13	Content Creation	Functional	Content Authoring, Validation, and Pedagogical Governance

No.	Title	Type	Category
14	Student Classroom Assignment Sharing	Functional	Teacher Classroom and Worksheet Management
15	Selection of Predefined Worksheets	Functional	
16	Instructional context characterization	Functional	
17	Review of Proposed Learning Objects	Functional	
18	Personalized Worksheet Generation	Functional	Adaptive Recommendation and Worksheet Generation
21	Present All Active Worksheet	Functional	Learner Interaction and Worksheet Execution
22	Worksheet completion by Student	Functional	
23	Edit Worksheet Response fields	Functional	
24	Support Blended Use	Functional	
25	Feedback on Enjoyment and Experience	Functional	
26	Teacher Evaluate learners work	Functional	Assessment, Monitoring, and Adaptive Feedback Loop
28	High Degree of Personalization	Non-Functional	Pedagogical Quality and Personalization
29	Support for the Development of the 4Cs	Non-Functional	

No.	Title	Type	Category
30	Teacher Interface Usability	Non-Functional	Usability and User Experience
31	Low Interaction Complexity	Non-Functional	
32	Timely Worksheet Generation	Non-Functional	Reliability, Availability, and Resilience
33	Efficient Data Retrieval	Non-Functional	
34	Efficient Processing of Educational Data	Non-Functional	
35	Reliability of Core Functions	Non-Functional	Scalability, Extensibility, and Interoperability
36	Reduction of Failure Propagation	Non-Functional	
37	Resilience Under Changing Workload	Non-Functional	
38	Service Continuity During Evolution	Non-Functional	
39	Extensibility of adaptive frameworks	Non-Functional	Maintainability, Modularity, and Testability
40	Openness to future Integration	Non-Functional	
41	Secure Data Storage and Prevention of Unauthorized	Non-Functional	Security, Privacy, and Data Protection

No.	Title	Type	Category
42	Integrity of Educational Data	Non-Functional	Data Integrity and Consistency
43	Consistency Across Components	Non-Functional	
45	Versioning and Operational Manageability	Non-Functional	Deployability and Operational Support

3.2.1 Functional Requirements

The following table provides an overview of the functional requirements of the platform, organized by feature area. Full specification details for each requirement, including prerequisites, success scenarios, and post-conditions, are provided in Appendix B.

User and Role Management

Having many different stakeholders in a platform means each has varying duties and access privileges that shape the platform's foundation. On those types of platforms, it is essential to the platform's design to deliver foundational functionalities. Students, teachers, content producers, educational specialists, and administrators must all be distinguished by the system. The system should ensure that each stakeholder can access only the parts of the platform permitted by their pedagogical duties and administrative level. This requirements section supports controlled access, task specialization, and a consistent platform workflow.

FR1. Support for Distinct user Roles [Functional]

The platform must offer unique user roles, such as student, teacher, content developer, educational expert, and administrator, to reflect the system's differentiated pedagogical and administrative workflows.

FR2. Role based Access Control [Functional]

The platform must enforce role-based permissions so that each stakeholder can only access functions and data that are relevant to their duties, ensuring controlled use of platform services and content.

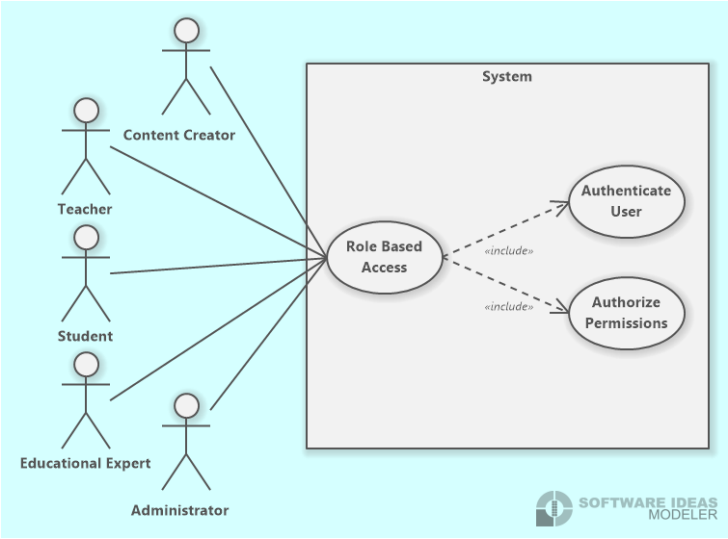


Figure 3.1. Role based Access Control Use Case Diagram

FR3. Administrative Management [Functional]

The platform shall allow administrators to manage all the content of the platform and allow them to delete content to support secure and organized system administration.

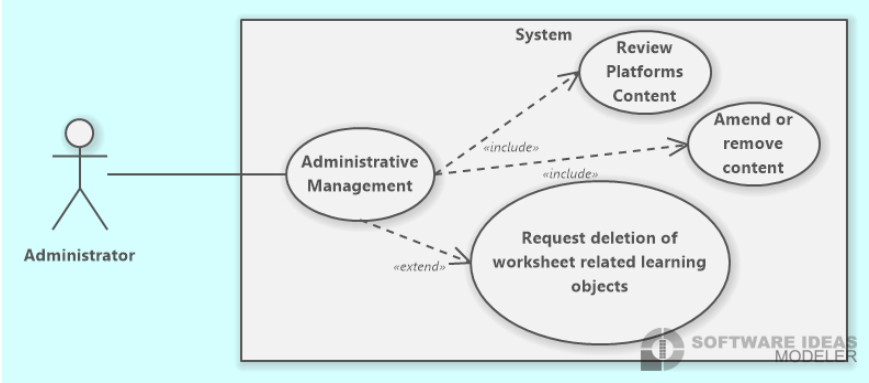


Figure 3.2. Administrative Management Use Case Diagram

Learner Profiling and Adaptation Setup

The foundation of the platform's adaptability is learner profiling. The system must first create and consistently maintain a structured learner model in order to provide customized

worksheets. Demographic data, learning style preferences, performance metrics, and behavioral data should all be included in this model. The learner profile is presented as the primary mechanism enabling adaptation in both the literature and the proposed platform architecture. As a result, this requirements section establishes the informational foundation for worksheet personalization, sequencing, and future recommendations.

FR4. Initial Learner Profile Creation [Functional]

During the first use of the platform, an initial learner profile is created to serve as the foundation for adaptive personalization. This initialization of the profile should be done using pedagogically authorized questionnaires to which the user should respond upon encountering a learning style.

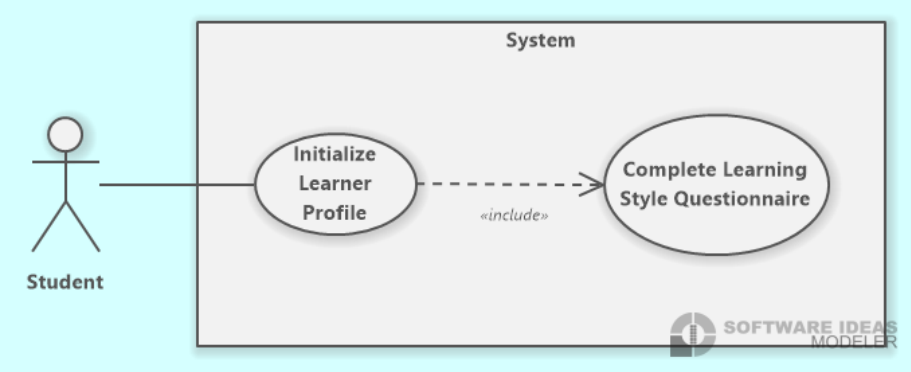


Figure 3.3. Initial Learner Profile Creation Use Case Diagram

FR5. Collection of Learner Information [Functional]

The platform will collect demographic and educational data essential to learner identification and classification, such as grade level and other profile characteristics required for adaptation.

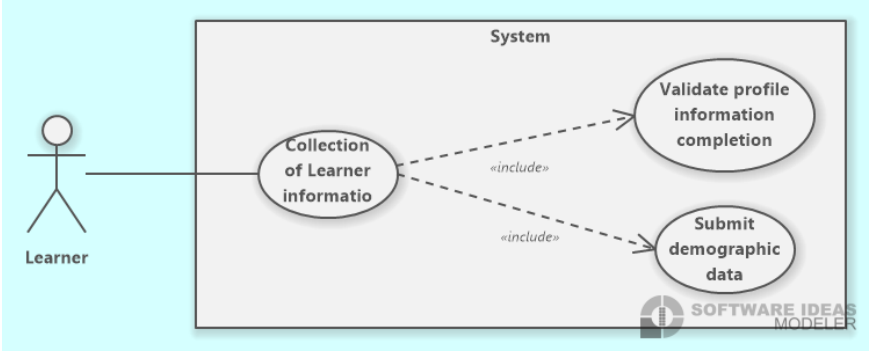


Figure 3.4. Collection of Learner Information Use Case Diagram

FR6. Dynamic Profile Update [Functional]

Following worksheet completion, the platform will update the learner profile with performance, feedback, and behavioral data to ensure that future recommendations are tailored to the learner's current needs.

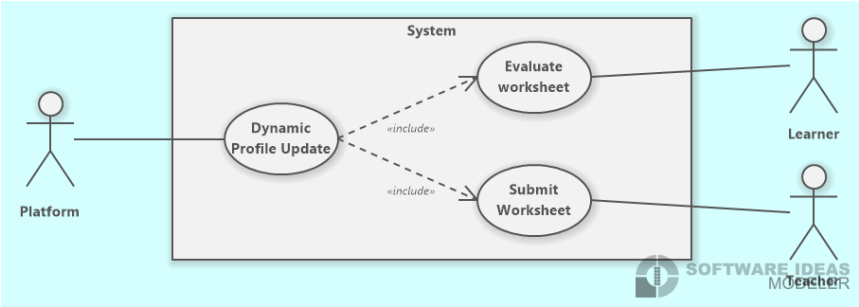


Figure 3.5. Dynamic Profile Update Use Case Diagram

FR7. Storage Adaptive Learner Data [Functional]

Following worksheet completion, the platform will update the learner profile with performance, feedback, and behavioral data to ensure that future recommendations are tailored to the learner's current needs.

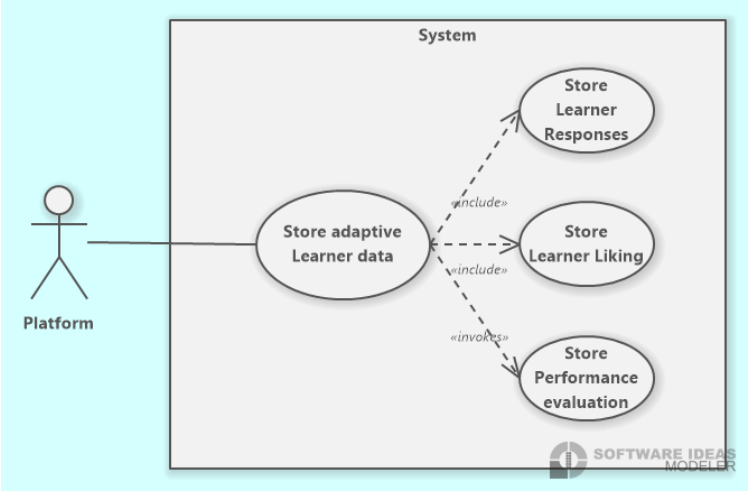


Figure 3.6. Storage Adaptive Learner Data Use Case Diagram

Curriculum, Learning Content, and Pedagogical Resource Management

The platform's recommendation algorithm is the core of the functionality. To achieve high efficiency of the platform, we need to have structured learning content. The system requires mechanisms to store data on learning subjects, learning methods, and learning objects in a consistent, structured format. The curriculum elements and the learning materials should be linked

through a structure with metadata that describes the pedagogical area and the cognitive level. This structured representation allows the platform to find and combine appropriate resources during worksheet generation.

FR8. Learning Subject Management [Functional]

The platform shall support the creation, storage, and management of learning subjects required for worksheet preparation and curriculum selection.

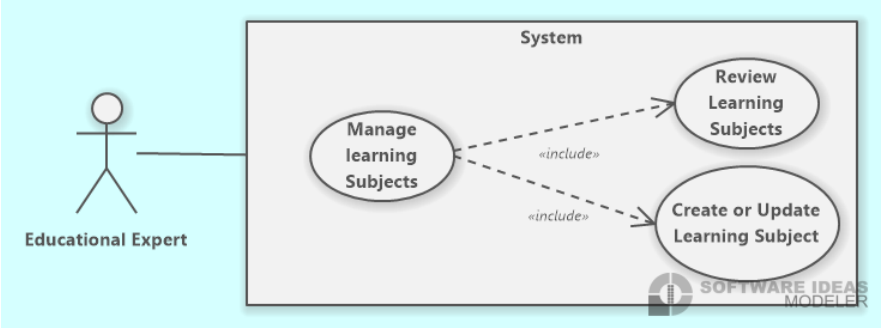


Figure 3.7. Learning Subject Management Use Case Diagram

FR9. Hierarchical Curriculum Representation [Functional]

The platform must show curriculum structure hierarchically, including syllabus, and subject area, to assist teachers in making structured instructional decisions.

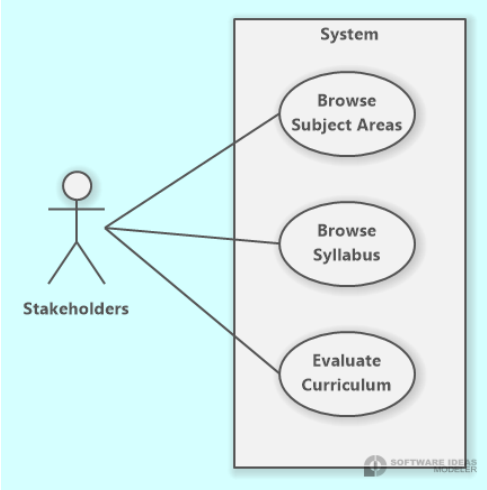


Figure 3.8. Hierarchical Curriculum Representation Use Case Diagram

FR10. Support Digital and Non-Digital Tools [Functional]

The platform must enable both digital and non-digital learning resources in order to function in blended learning environments that include both classroom and home settings.

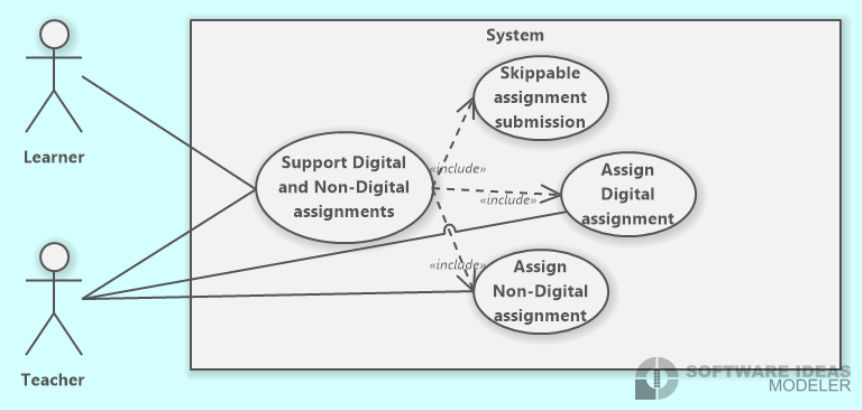


Figure 3.9. Support Digital and Non-Digital Tools Use Case Diagram

FR11. Learning Object Metadata Management [Functional]

The platform must contain metadata for learning objects, such as subject, difficulty, grade level, and other descriptive properties used for filtering and recommendation.

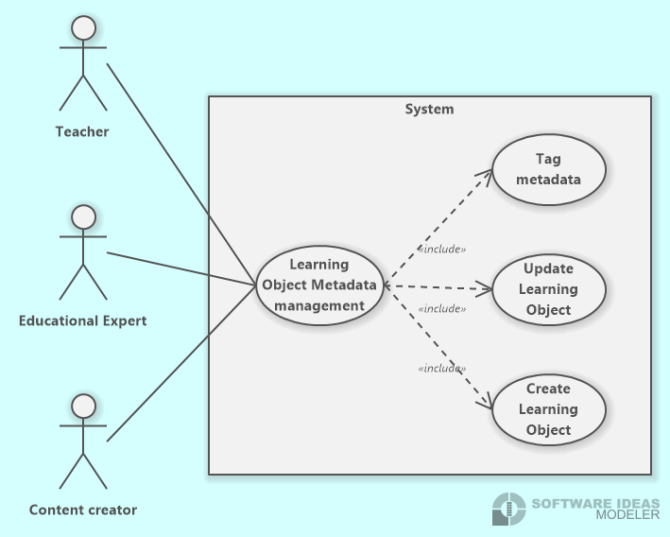


Figure 3.10. Learning Object Metadata Management Use Case Diagram

FR12. Cognitive Level Classification of Activities [Functional]

The software will classify learning activities and learning objects based on cognitive level, ensuring that adaptive worksheet production follows an educationally coherent progression.

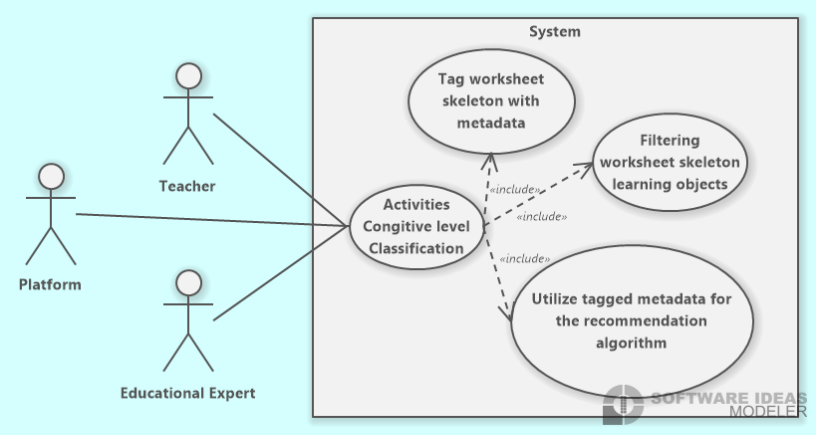


Figure 3.11. Cognitive Level Classification of Activities Use Case Diagram

Content Authoring, Validation, and Pedagogical Governance

The platform does not rely entirely on automated operations. It also requires human pedagogical control to ensure that its content is of high quality, relevant, and educationally valid. As a result, content production and validation are classified as separate functional categories. Content creators are responsible for creating and improving learning objects, whilst educational experts validate contributed material and keep the system's pedagogical knowledge base up to date. These requirements ensure that adaptive judgments are based on educational intent, rather than technical scoring algorithms.

FR13. Content Creation [Functional]

The platform should enable users with the necessary permissions to create content. Users should be able to create and update learning objects, subjects, and methods to expand the platform archive and address pedagogical demands and curriculum progression.

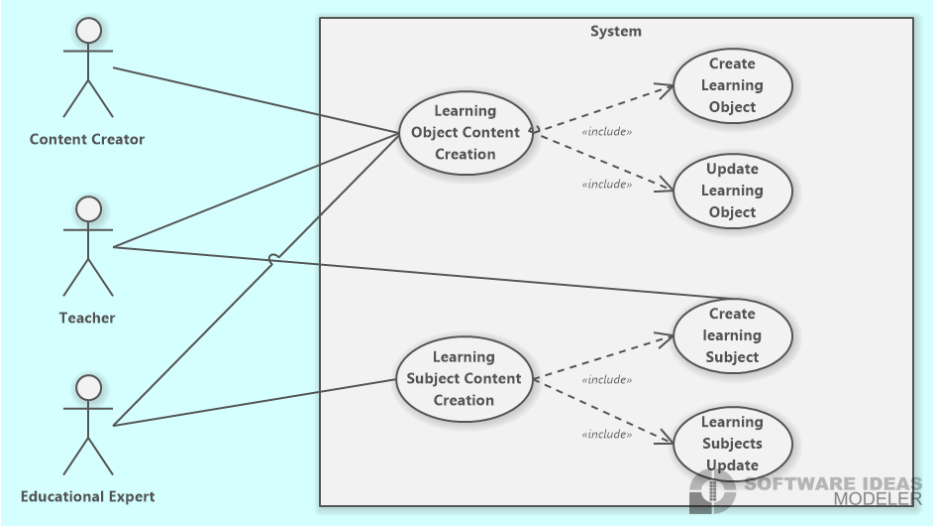


Figure 3.12. Content Creation Use Case Diagram

Teacher Classroom and Worksheet Management

Within the proposed platform, the teacher remains the primary instructional actor. The technology is designed to supplement, not replace, instructor judgment by offering a flexible setting for classroom organization and worksheet preparation. Teachers must therefore be able to share worksheets with learners, select curriculum elements, and review proposed learning resources and the learner's profile. This category includes the functions that allow teachers to orchestrate personalized learning activities within a blended learning environment.

FR14. Student Classroom Worksheet Sharing [Functional]

The platform will enable teachers to share worksheet skeleton with students in their classrooms, allowing for individualized worksheet generation within a course environment.

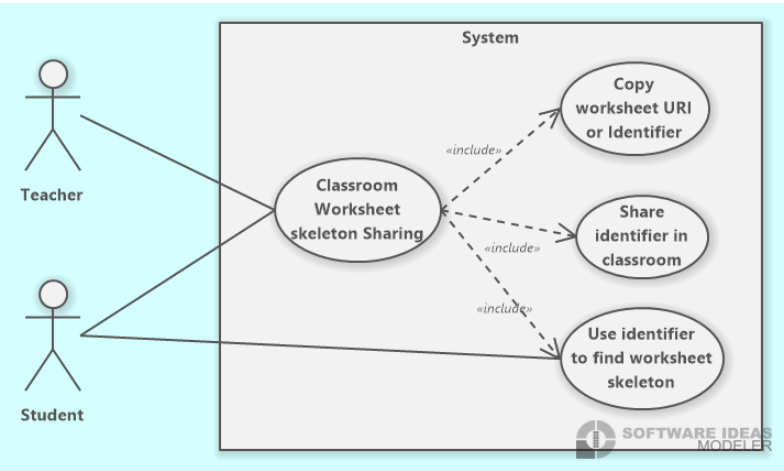


Figure 3.13. Student Classroom Worksheet Sharing Use Case Diagram

FR15. Selection of Predefined Worksheets [Functional]

The platform allow teachers to select predefined generic worksheets provided in the platform archive as a basis for instructional adaptation and reuse.

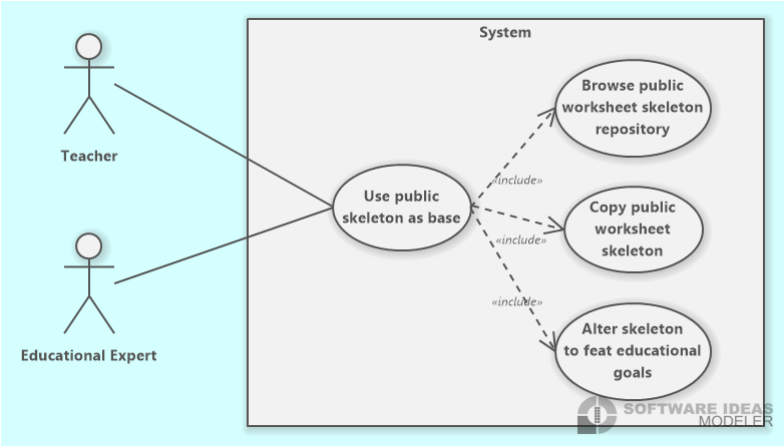


Figure 3.14. Selection Of Predefined Worksheets Use Case Diagram

FR16. Instructional context characterization [Functional]

The platform will allow teachers to select the educational level, area of study, learning subjects, and learning resources that are important to worksheet preparation.

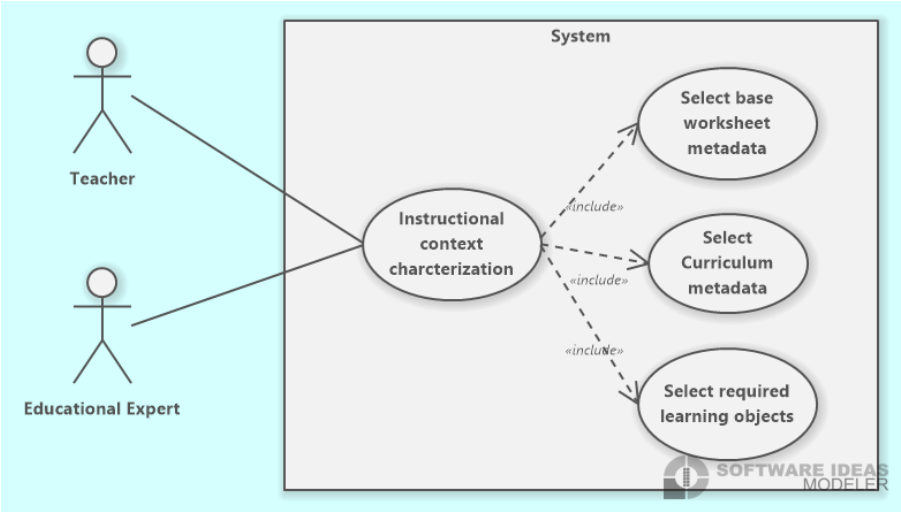


Figure 3.15. Instructional context characterization Use Case Diagram

FR17. Review of Proposed Learning Objects [Functional]

The platform allow teachers to review and adjust the platform's proposed learning objects before final assignment to learners.

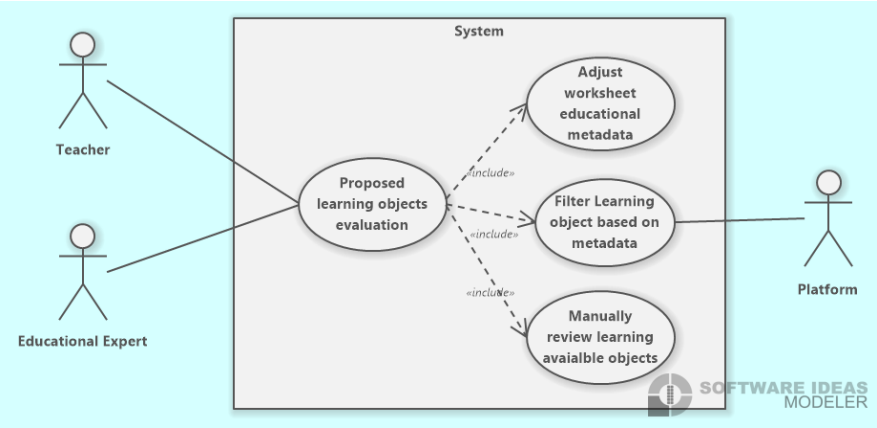


Figure 3.16. Review of Propose Learning Objects Use Case Diagram

Adaptive Recommendation and Worksheet Generation

The platform's core functionality comprises adaptive recommendations and worksheet generation. The worksheet engine serves as the primary orchestration mechanism, combining curriculum structure, pedagogical approaches, Bloom's taxonomy levels, learner profile data, and recommendation scores to deliver customized learning and assessment activities. The platform introduces a hybrid recommendation technique that combines content-based and collaborative signals while maintaining instructional structure and pedagogical integrity. This category subsequently includes the system's primary intelligence layer.

FR18. Personalized Worksheet Generation [Functional]

The platform will create personalized worksheets for each learner based on their profile, preferences, and pedagogical requirements.

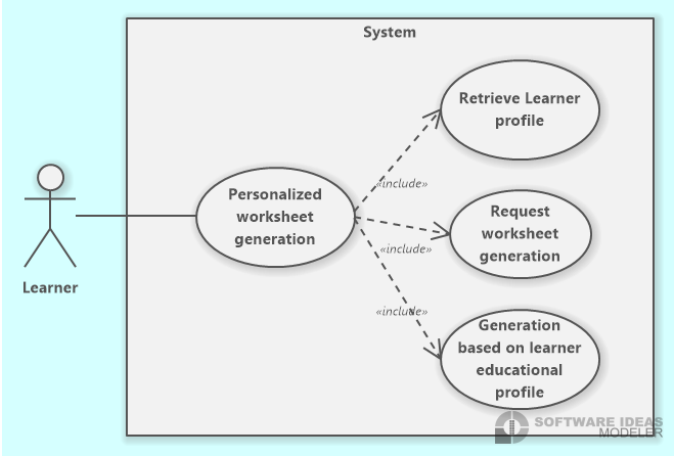


Figure 3.17. Personalized Worksheet Generation Use Case Diagram

FR19. Use of Learning Style on Recommendation [Functional]

The platform shall use learning-style information as part of the recommendation and worksheet assembly process.

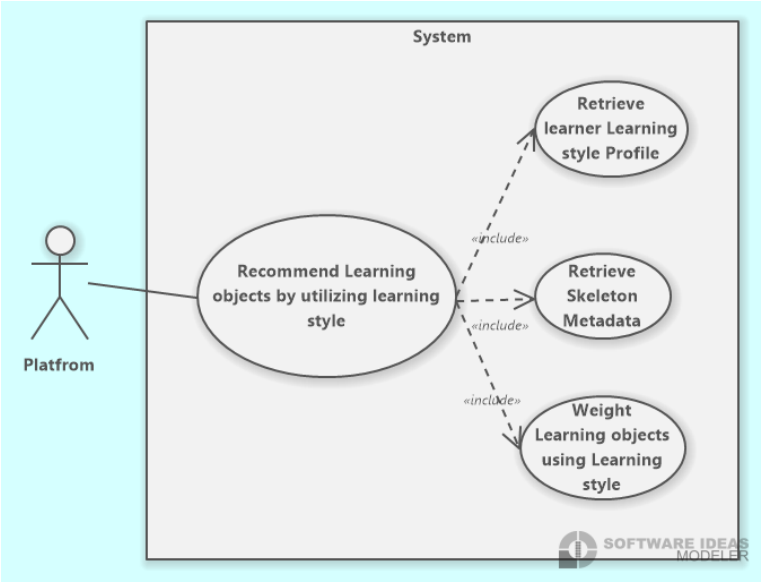


Figure 3.18. Use of Learning Style on Recommendation Use Case Diagram

FR20. Hybrid Recommendation Logic [Functional]

To improve recommendation quality, the platform will combine content-based and collaborative recommendations based on similar students and learning objects during the scoring process. To improve recommendation quality, the platform will combine content-based and collaborative recommendations based on similar students and learning objects during the scoring process.

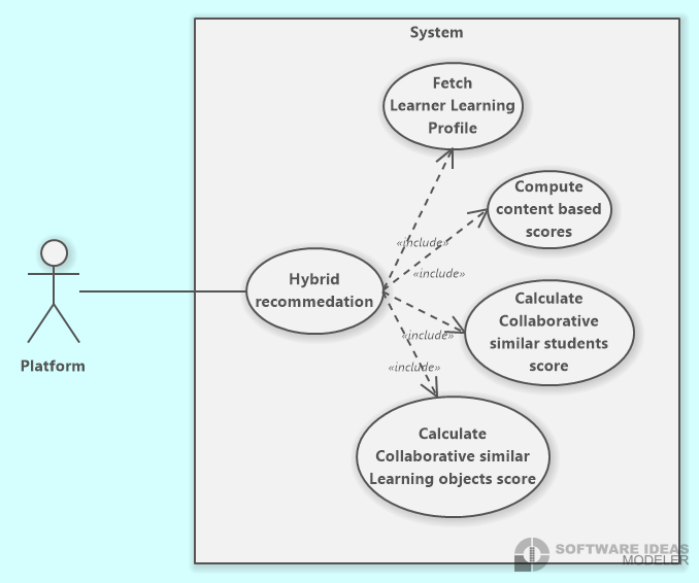


Figure 3.19. Hybrid Recommendation Logic Use Case Diagram

Learner Interaction and Worksheet Execution

The platform must also allow for direct learner interaction with allocated educational materials. Because the proposed system brings classroom learning home, students want a consistent interface to access virtual classroom learning materials, view active worksheets, complete activities, and provide feedback on their learning experiences. These interactions are not purely operational. They also provide crucial information for future adaptation. This category encompasses both access-oriented and feedback-oriented learner functions.

FR21. Present All Active Worksheet skeletons [Functional]

The platform present currently available worksheet skeletons to each student for selection and completion.

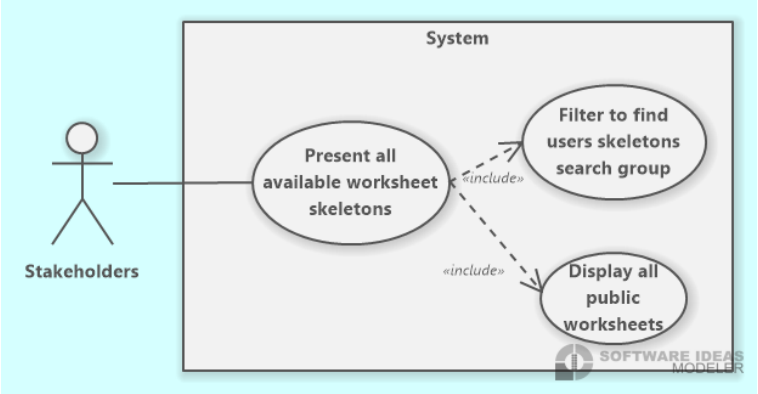


Figure 3.20. Present All Active Worksheet skeleton Use Case Diagram

FR22. Worksheet completion by Student [Functional]

The platform allow students to read and complete assigned worksheets within the platform environment.

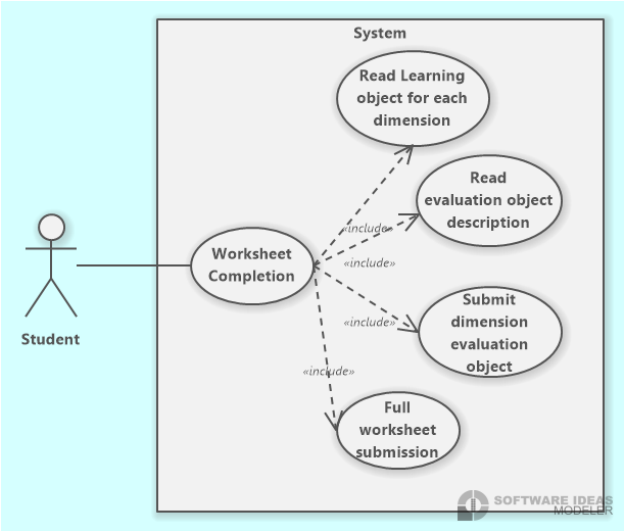


Figure 3.21. Worksheet Completion by Student Use Case Diagram

FR23. Edit Worksheet Response Fields [Functional]

The platform allow students to edit all response fields within worksheet activities where learner input is required before the final submission of the worksheet.

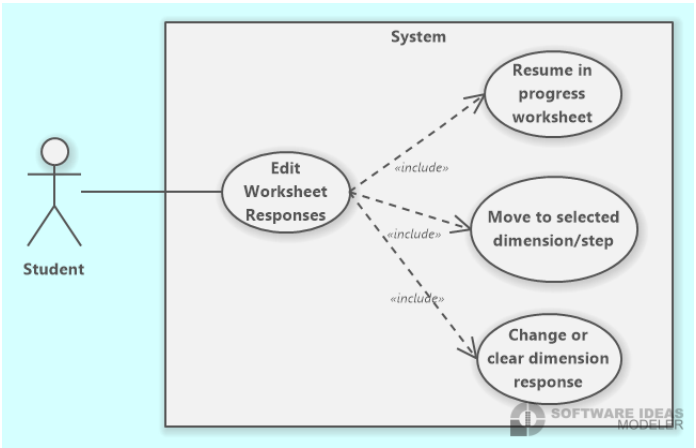


Figure 3.22. Edit Worksheet Response Fields Use Case Diagram

FR24. Support Blended Use [Functional]

The platform support worksheet use in both classroom and out-of-classroom settings in accordance with the blended learning model.

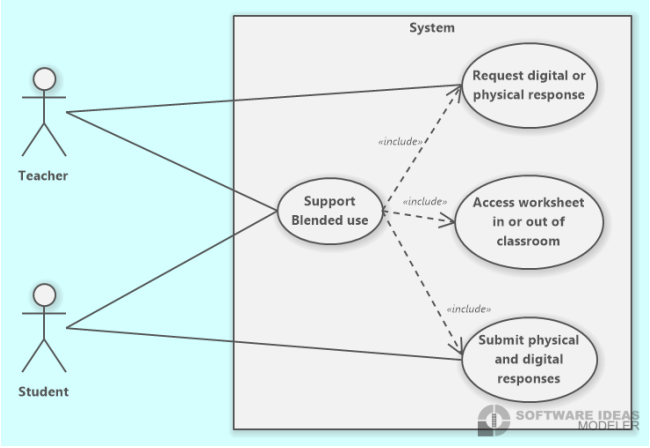


Figure 3.23. Support Blended Use Use Case Diagram

FR25. Feedback on Enjoyment and Experience [Functional]

The platform allow students to provide feedback on worksheet enjoyment and overall learning experience.

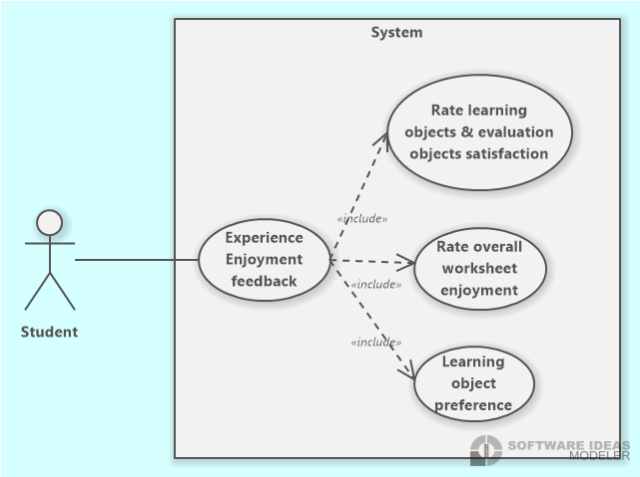


Figure 3.24. Feedback on Enjoyment and Experience Use Case Diagram

Assessment, Monitoring, and Adaptive Feedback Loop

The platform's adaptive cycle can only function properly if learner activity is monitored, teacher assessment is implemented, and the resulting data is fed back into the learner model. As a result, assessment and monitoring are handled as independent functional areas. During worksheet execution, the system must track student progress and responses, make this information available to teachers, and save teacher assessments. The modified performance data must then be sent back to the profile component so that future recommendations reflect the learner's changing progress, satisfaction, and cognitive development.

FR26. Teacher Evaluate learners work [Functional]

The platform shall make learner progress and performance data available to teachers for instructional monitoring and intervention.

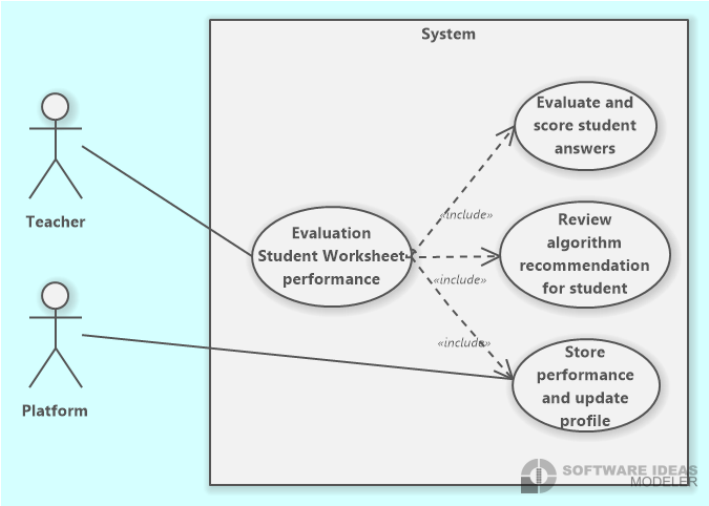


Figure 3.25. Teacher Evaluate learners work Use Case Diagram

FR27. Use of Evaluation Outcomes for future adaptations [Functional]

The platform shall use evaluation outcomes to update future personalization and recommendation decisions.

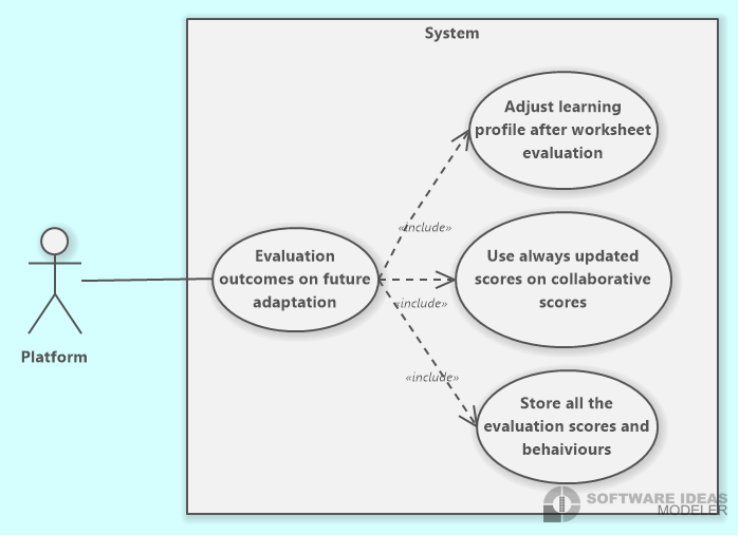


Figure 3.26. Use of Evaluation Outcomes for future adaptations Use Case Diagram

3.2.2 Non-Functional Requirements

The following table provides an overview of the non-functional requirements of the platform, organized by quality attribute category. Full specification details are provided in Appendix B.

Pedagogical Quality and Personalization

Because the platform is designed to facilitate adaptive blended learning, pedagogical excellence and meaningful personalization are essential qualities rather than optional additions. The system must ensure that customized recommendations are not only technically correct but also pedagogically understandable, instructionally aligned, and sensitive to learner requirements. This requirement category stems directly from the platform's theoretical viewpoint, which includes adaptive learning, blended learning, Bloom's Revised Taxonomy, and the 4Cs as mutually reinforcing design concepts. In this context, quality is defined as instructional coherence, relevance to the learner profile, and the ability to maintain educational aims while adjusting content to learners' cognitive levels.

FR28. High Degree of Personalization [Non-Functional]

The platform shall provide a high degree of personalization by adapting educational content to learner profiles, preferences, performance patterns, and learning-style information.

FR29. Support for the Development of the 4Cs [Non-Functional]

The platform shall support the long-term educational goal of fostering the 4Cs through structured and adaptive learning pathways.

Usability and User Experience

Usability is an important quality characteristic of the proposed platform, as it must enable both teachers and students to interact effectively in authentic educational environments. The dissertation clearly assesses the platform using the Technology Acceptance Model and the System Usability Scale, suggesting that simplicity of use, perceived usefulness, clarity, and user-friendliness are important considerations. For teachers, usability influences lesson planning, worksheet review, and classroom management. It impacts students' access to worksheets, assignment completion, and continued engagement. A functional platform is consequently required for acceptance, long-term use, and significant educational impact.

FR30. Teacher Interface Usability [Non-Functional]

The platform shall provide a simple and clear interface for teachers during classroom setup, worksheet preparation, and review evaluation objects.

FR31. Low Interaction Complexity [Non-Functional]

The platform shall minimize unnecessary interaction complexity so that essential tasks can be completed without extensive technical support.

Reliability, Availability, and Resilience

Because the platform is meant to facilitate blended learning activities in both classroom and home settings, it must be reliable and available throughout routine educational use. Reliability is closely tied to the microservice-based architecture paradigm, which distributes responsibility across autonomous services, lowering the danger that a failure in one component may jeopardize the entire system. In this context, resilience refers to the system's ability to function despite variable loads, partial failures, or changes in use conditions. These characteristics are especially relevant in educational environments, as unpredictable system performance can disrupt instruction and compromise user trust.

FR32. Timely Worksheet Generation [Non-Functional]

The platform shall generate personalised worksheets within response times suitable for authentic educational use.

FR33. Efficient Data Retrieval [Non-Functional]

The platform shall use lightweight communication mechanisms between internal components to reduce latency during adaptive operations and must support the quick retrieval of learner and content data required for adaptive recommendation, worksheet building, and general display of accessible information with very short data retrieval times and no need for repetitive requests.

FR34. Efficient Processing of Educational Dat [Non-Functional]

The platform shall maintain acceptable performance while processing structured and semi-structured educational data.

Scalability, Extensibility, and Interoperability

The proposed platform is designed to expand over time, embracing new learners, new learning resources, additional learning-style models, and possibly external educational services. As a result, the architecture must accommodate development without extensive redesign. The dissertation describes microservices as a flexible and scalable technique for adaptive learning settings. The platform architecture was chosen to provide maintainability, scalability, and extensibility. Interoperability is particularly vital, as adaptive platforms increasingly communicate with external repositories, assessment systems, and digital learning tools via APIs.

FR35. Reliability of Core Functions [Non-Functional]

The platform shall provide reliable behavior during worksheet creation, recommendation, execution, and evaluation.

FR36. Reduction of Failure Propagation [Non-Functional]

The platform shall reduce the risk that failure in one functional area compromises the operation of the whole system.

FR37. Resilience Under Changing Workload [Non-Functional]

The platform must be able to operate reliably even under shifting workload conditions and routine educational usage.

FR38. Service Continuity During Evolution [Non-Functional]

The platform must ensure service continuity throughout modular upgrades and steady system evolution, if possible.

Maintainability, Modularity, and Testability

Long-term maintainability is critical for a platform that integrates adaptive recommendation, instructional structuring, and multi-role interaction. Both the dissertation and the accompanying article are strategic architectural options that enable independent creation, flexible evolution, and quicker upgrades of platform components. Clean architectural separation also increases testability by making it easier to validate services individually. These characteristics are significant not just for implementation efficiency, but also for the platform's scientific worth, as a well-structured system is easier to refine, analyze, and expand in future work.

FR39. Extensibility of adaptive frameworks [Non-Functional]

The platform must be adaptable to facilitate the integration of additional services, suggestion signals, learning-style models, and pedagogical resources without necessitating significant redesign.

FR40. Openness to future Integration [Non-Functional]

The platform will be available for future integration of new educational tools, repositories, and recommendation algorithms.

Security, Privacy, and Data Protection

The platform manages sensitive educational and learner data, including performance records, preferences, questionnaire replies, and profile information. As a result, security and privacy are essential quality criteria, and the credential is always stored encrypted. The data is stored securely, with no third-party access, and users can request account termination via email, which deletes sensitive data and anonymizes the remaining information. Together, these challenges highlight the critical need for appropriate educational data management.

FR41. Secure Data Storage and Prevention of Unauthorized Access [Non-Functional]

The platform must securely save learner information, worksheets, and evaluation data, with authorization data encrypted, and the system must prohibit unauthorized third-party access to stored educational data.

Data Integrity and Consistency

The platform's adaptability is based on the accuracy, availability, and consistency of learner and educational data. Because the architecture divides responsibilities across multiple services and databases, the system must ensure that data remains correct and consistent when it is created, modified, and reused across components. The dedicated databases for data integrity, although the dissertation acknowledges that microservices introduce coordination challenges related to security and data consistency. Data integrity is thus a distinct quality criterion that supports dependable personalization and trustworthy analytics.

FR42. Integrity of Educational Data [Non-Functional]

The platform shall preserve the integrity of learner, worksheet, and content data across all functional areas.

FR43. Consistency Across Components [Non-Functional]

The platform shall manage coordination among its internal components in a way that minimizes data inconsistency.

Deployability and Operational Support

The final category focuses on the platform's practical implementation and operational management. Because the design is based on independent services, the deployment process must be modular, automated, and consistent across all environments. The platform deployment uses Docker containerization and Jenkins-supported CI/CD to ensure reliable build, test, and deployment. These characteristics are significant because they reduce manual labor, increase reproducibility, and ensure the smooth operation of a complicated educational system.

FR44. Support for Modular Deployment and Automated Build and Deployment Support [Non-Functional]

The platform shall support modular deployment of its major components across technical environments and shall support automated build, test, and deployment processes in order to improve operational consistency.

FR45. Versioning and Operational Manageability [Non-Functional]

The platform shall support reliable versioning and operational management of independently evolving components.

Chapter 4 - Architecture and Design

4.1 Architecture

This chapter presents the architectural design of the adaptive learning platform, as shown in Figure X. It shows how the system is structured, how functionality is split across its components, and how the platform's requirements are implemented from a technical standpoint. The platform architecture is designed in accordance with the pedagogical constraints and limitations outlined in Chapter 3.1, as well as the functional and non-functional requirements. In particular, the architecture aims to support adaptability, scalability, and flexibility while keeping a clear separation between adaptive learning, data administration, pedagogical logic, and presentation. To preserve the pedagogical requirements of the platform and be flexible, the system is divided into distinct architectural parts that allow for independent development and maintenance of each service. This architecture allows us to minimize the dependencies between the system components and allows to implement an adaptable learning platform that supports all the pedagogical needs required for a platform that supports ongoing learning.

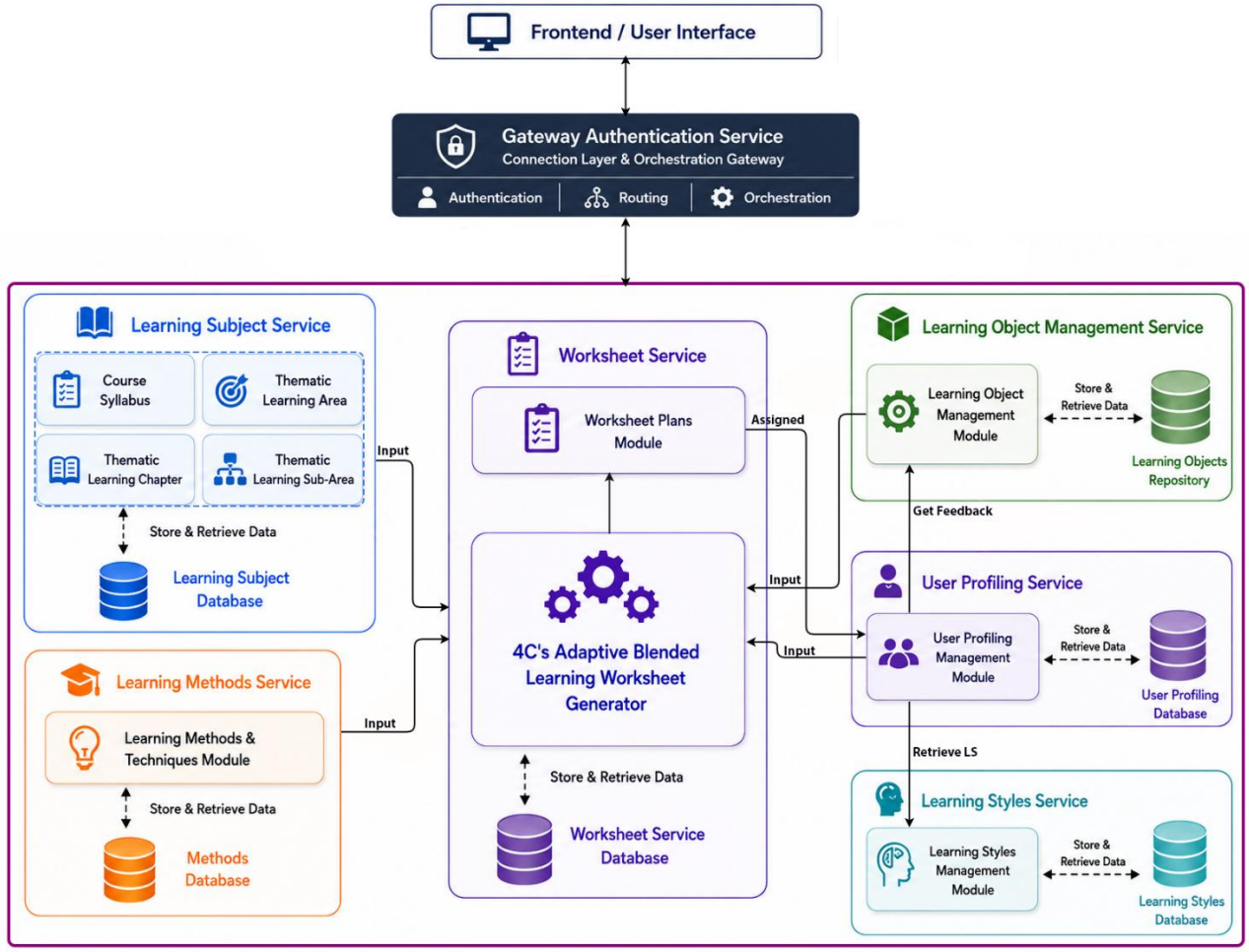


Figure 4.1. Architecture Diagram

4.1.1 Architectural Overview

This section describes the architectural design overview of this adaptive learning platform. These days, sophisticated software systems must follow strict design criteria. These days, there are a lot of requirements, such as high scalability, flexibility, and the need for systems that may change on their own without affecting the rest of the system. In contrast to a monolithic architecture, which is a single implementation with all components as a single element, with no distinct sections and all parts tied together, a microservices architecture is designed to meet these demands [92]. The adaptive learning platform shown in Figure X is designed using a modern software architecture, namely microservices. The system is based on a pillar of the microservices architecture, which is Decomposition. With the Decomposition principle and Functional Modularity, the system has been

divided into separate, autonomous services. Each service has been separated based on unique business functionalities into simple, manageable and maintainable parts based on the unique business functions of the platform [92]. The system is partitioned into 7 specialized modules: Gateway Authentication, User Profiling, Worksheets, Learning Styles, Learning Methods, Learning Subjects, and Learning Object Management.

These modules can interact through lightweight mechanisms while maintaining their autonomy, thanks to their strong functional cohesion and loose coupling. Because of its modularity, the platform can evolve independently, allowing the replacement or updating of specific parts, such as the Worksheet Generator, without requiring a full system rebuild [92], [93]. A very crucial characteristic of this architecture is the need to have decentralized data management. Each microservice has its own private database and repository, as shown in the architectural design. By avoiding the "anti-pattern" of a single shared database, this preserves service autonomy by preventing hidden dependencies on one another's data structures [92], [93].

The core of the platform is the Worksheet generation Engine, which is handled by the Worksheet service. This component integrates input from most services and is responsible for producing the worksheet for each student. Dividing services and distributing each service's responsibility improves fault tolerance; for example, if a service like Learning Subject or Learning Object does not necessarily cause a system crash or affect any other service, it can continue to function independently [92].

The three key elements of the microservices implementation in this Adaptive Learning Platform architecture are on-demand scalability, which allows the platform to scale when any individual component encounters high demand [92], [94]. Technology diversity is a critical element because it allows each service to be developed using the technology that best serves its needs. The third key element is continuous delivery, which enables automation and autonomous deployment [94] The architecture shortens the development lifecycle time required to release a new version that introduces a new feature or fixes a bug [93].

4.1.2 Architectural Layers

In the Architectural Layers chapter, we provide a thorough description of the structure of this Adaptive Learning platform, which is built on functional responsibilities to achieve an appropriate separation of concerns [C3 3]. The platform moved from a monolithic architecture that

encapsulates all the layers in one build to a robust microservices three tier model architecture consisting of a presentation layer, a business logic layer, and data layer. The platform's architecture is composed of a collection of compact, self-contained, and independently deployable services. This layered architecture is designed to allow building platforms with enhanced modularity and flexibility [93]. This architecture has been selected to avoid a rigid, single-block deployment by distributing each functionality across separate, specialized services. This organized structure allows to develop a platform with extensive pedagogical rules that evolve the internal logic without the need for the whole system reassembly in each system update [92], [93].

By partitioning the architectural design into distinct levels, the platform ensures that each layer is decoupled and serves its own requirements. The Presentations Layer comprises the architectural components that present content to clients. This layer is decoupled from the backend services that handle the platform's core logic and form its core engine. The first component of the platform is the frontend web interface that is the way that the user interacts with the platform. Through this web interface, the user can access all the pedagogical content on the platform and, at the same time, interact with, generate, and execute worksheets triggered by user interactions. The user can engage with, generate, and run worksheets that are triggered by user interactions while simultaneously accessing all the platform's pedagogical content through this web interface [92], [95]. Furthermore, another structural component of the presentation layer is an API gateway, which serves as the interface between the web interface and the Application Logic Layer. This part isolates the presentation from the rest of the layers, allowing it to remain independent of backend service complexity and avoiding the need to modify the logic. Communication between the two layers is handled through the gateway and a lightweight RESTful API over HTTP. The platform can scale either the frontend or the logic layer independently, thanks to this separation, which also provides increased flexibility [92].

The Application Logic Layer serves as the platform's logic core engine. The core of this platform is not a single monolithic block but a collection of services that have been functionally decomposed into smaller, autonomous microservices tailored to specific business needs [92], [95]. As shown in the architectural diagram in Figure X, the individual microservice modules are: Gateway Authentication, User Profiling, Worksheets, Learning Styles, Learning Methods, Learning Subjects, and Learning Object Management. Each module functions independently within the Application Logic Layer and is a modular component within the platform's entire core

logic engine [95]. The platform's core microservice is the worksheet module, which communicates with many other services and enables the personalized generation of worksheets for each learner. High functional cohesion and loose coupling are ensured by the microservices design, which allows each service to be fixed or have educational rules modified independently of the rest of the services swarm, usually without affecting the other services [92].

The Data Layer is a critical part of any application designed with this type of architecture. The Data Layer decentralized data management, which is necessary to preserve service autonomy, is directly related to the autonomy of each service, as mentioned in the earlier section about the Application Logic Layer [92], [95]. In this architecture, each microservice has its own private database and repository. This design enforces a critical rule that each service should follow: each database accessed from only one service, which ensures that it doesn't have dependencies on any other database schema. The challenge of ensuring data consistency throughout the distributed system is introduced by this decentralization, even while it permits each module to use the best available storage technology (heterogeneous storage). To solve this, the platform uses compensating mechanisms or asynchronous communication rather than distributed transactions to ensure data consistency across multiple independent repositories [92], [93], [95].

4.1.3 Data Model overview

The Adaptive Learning platform is based on a microservices architecture, leading to a data model that follows the principle of decentralized data management, which is necessary to maintain the microservices' autonomy. This platform diverges from conventional monolithic designs that depend on a singular, shared database by distributing data across specialized repositories, allowing each microservice to encapsulate its own data structures and persistence algorithms [92], [93], [95].

Due to the decentralized nature of the microservices architecture, each functional module has private, decentralized data ownership, with each module having access to its own database. By having no other services access the database, the design eliminates the hidden dependencies that can be common in monolithic systems. Each service manages its own database and is independent, allowing it to make changes without any direct impact on other modules [93], [95]. By adopting a centralized approach, the technology diversity enables multiple types of databases tailored to the specific needs of each service. While some modules might need traditional databases due to the

high need for relational data, SQL databases might use structured relational data. Other services might need a more flexible database scheme and might choose NoSQL document databases. This flexibility enables efficient design and development that consistently addresses and solves the business problems of each service in its respective domain [92], [93]. Additionally, this decentralization helps to keep the database consistent and enhances the fault tolerance and scalability of the database and system. Domain Driven Design (DDD) defines the bounds of these decentralized data models. By defining a specific "bounded context" for each module, such as the exact data needed to create a Work Sheet Plan, the platform ensures that microservices are highly coherent and that their data models accurately match the business processes they serve [92].

4.2 Core Services

4.2.1 Gateway Authentication Service

The Gateway Authentication Service is responsible mainly for the secure entrypoint on the platform's data and functionality for all users. The service manages the registration and identity verification process for all the platform roles, like students, instructors, educational experts, content creators, and administrators. The service uses authentication and permission to protect user data and grant access to each user, whether public, administrative, or private, based on their assigned credentials. In addition to secure entry-point functionality, the service implements gateway functionality that receives API calls and routes them to the platform's corresponding services. The Gateway Authentication Service does not communicate with other services apart from the role of the gateway. The platform accepts all the platform's requests and takes the role of being center piece of the platform, acting as an entry to the whole platform's Rest APIs ecosystem by acting as a reverse-proxy entry point that routes and secures all the API requests and communication between the microservices.

The Gateway Authentication service provides an important pedagogical purpose by identifying user roles and facilitating appropriate interactions and data within educational platforms. By handling the pedagogical privileges on the platform, delegates the management of responsibilities and ensures that each role has access to the relevant parts of the platform. This role management on the platform ensures, for example, that students have access to the appropriate learning materials, and that while the learner educates and trains themselves, the instructor retains the essential access and control to monitor the learner's progress.

4.2.2 User Profiling Service

One of the most critical purposes of the platform is data collection. The User Profiling service has the main purpose to shape the learners' learning profile by collecting data. The service collects and maintains user-specific data, including learners' demographic and session history information, as well as preferences and performance metrics. The service also processes data collected throughout the learners' journey on the platform and shapes each learner's learning profile based on recorded behaviour. This process implements an algorithm to build a model that handles the evolution of the learner's profile. By doing this tries to solve the “cold-start” problem and provides a data-driven personalized recommendation each time.

The service is accessed occasionally during each learner's journey on the platform. At first, the service has the first communication when the user responds to the learning style questionnaire. When the learner responds to the questionnaire, the Learning Style microservice contacts the User Profiling service and initializes the user profile by providing the basic profile demographic data and the response of the questionnaire, which provides an initial version of the user's learning preferences and abilities, and by using this to try to solve the “cold-start” problem. As a result, the platform has the necessary data to provide an appropriate recommendation when the worksheet service requests the object rating, similar students' data, and the student profile, enabling accurate worksheet customisation.

The User Profiling Service is the core of the adaptive educational platform's automation functionality. This automated personalization system creates a multi-dimensional profile of the learners and provides a new tool for the instructor that enables the ability to the teacher to identify knowledge gaps and learning difficulties, and allows for timely pedagogical interventions, and provides automatically worksheets that have been adapted to each individual learner's needs.

4.2.3 Worksheets Service

The core of the platform's functionality is the worksheet generation. The Worksheet service dynamically generates worksheets based on teacher-defined skeletons that provide the service with the required data and learning objects. These services use data from the learner's profile and personalized object ranking to change the generated worksheet based on the profile and the active syllabus of the relevant lesson.

The service has many communication channels with the rest of the ecosystem's microservices. The service serves as the platform's core engine, communicating with the rest of the services and collecting the required data to successfully generate personalized worksheets. First of all, the platform's functionality is the creation of teacher-defined worksheet skeletons that, based on the service, later generate personalized worksheets. Furthermore, when the service is requested by the learner to generate a worksheet, it communicates with services like Learning Styles, Learning Methods, and Learning Subjects to fetch the info related to pedagogical tagging of the worksheet skeleton. Following the retrieval of pedagogical information and learning objects from the Learning Object Management Service, the service communicates with the User Profiling service to obtain the necessary learning object ranking and learner profile information, enabling it to recommend the most appropriate learning and evaluation objects with the highest possible degree of precision.

The Worksheets Service holds a core, critical pedagogical role on the platform, shaping the platform's overall objective. It automates the creation of tailored learning materials, making differentiated education more practical. It enables instructors to maintain pedagogical control through templates while ensuring that each student receives assignments tailored to their cognitive development and sensory preferences, resulting in deeper engagement.

4.2.4 Learning Styles Service

One of the most critical purposes of the platform is data collection. The User Profiling service has the main purpose to shape the learners' learning profile by collecting a lot of data. The service collects and maintains user-specific data, including learners' demographic and session history information, as well as preferences and performance metrics. The service also processes data collected throughout the learners' journey on the platform and shapes each learner's learning profile based on recorded behavior. This process implements an algorithm to build a model that handles the evolution of the learner's profile. By doing this tries to solve the “cold-start” problem and provides a data-driven personalized recommendation each time.

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4.2.5 Learning Styles Service

The Learning Styles service serves two purposes: one as a repository and the other as a tool to classify a new learner's learning style profile. The service serves as an archive that stores all the required learning knowledge by providing added to the platform by the educational experts with text, hyperlinks, or videos in order to provide the required knowledge mainly for the instructors or the content creators to learn more about the learning styles and what each learning style serves and how it helps to use it to help the learners growth. On the other hand, the service enables quantitative analysis of responses to the learning styles questionnaire, helping resolve the "cold-start" problem, which is widespread across all educational platforms.

Most of the time, the service returns the information needed to display the full picture of the requested learning style to the frontend when a user, usually the Teacher, tries to educate themselves about a specific learning style. In this case, the service works as a RESTful API that returns all the data, including the hyperlinks, to useful files or videos to educate the user who visits the page. On the other hand, apart from providing the learning style info, the service provides the platform with the questions needed to use for each learning style questionnaire. When a learner attempts to access a worksheet that uses a learning style that the user has not experienced before, the platform requires the user to complete a questionnaire. When the learner submits the completed questionnaire, the service calculates the results, stores them, and sends them to the User Profiling service to set up the learner's profile for that learning style.

In this platform, the Learning Styles service focuses on a specific pedagogical role to perceive and process information about students' learning styles. Furthermore, using the questionnaires as a tool to paint the learners' educational profile helps to align information delivery with sensory channels, such as Visual, Audio, Reading, or Kinesthetic (VARK) preferences, improves academic performance and student satisfaction by making the learning process more intuitive.

4.2.6 Learning Methods Service

The Learning Method service has as its responsibility to primarily store and provide pedagogical learning methods, techniques, and strategies to equip instructors. Having this tool instructor can better utilize the platform and adapt the adaptive learning and logic in their courses' syllabus.

The service is technically a bucket of knowledge that is mainly called from the platform's front-end client. In that specific case, the instructor or the educational expert visits the frontend page, and the client fetches all the available learning methods in the platform. When a user selects any individual method, the client retrieves all the whole info related to that specific method or technique. The service then returns all text information as well as all hyperlinks to further in-depth resources, allowing the user to gain a thorough understanding of that particular item.

The pedagogical alignment of the instructional strategies provided by this service ensures that the instructors design the courses with the help of a system that targets the Zone of Proximal Development (ZPD) [5]. This pedagogical role is the responsibility of this service, which enables a curriculum that uses tools like Bloom's Taxonomy, the 4Cs, and learning methods to optimize the learning process and stimulate student growth without inducing frustration.

4.2.7 Learning Subjects Service

The Learning Subject service has a very clear purpose to maintain the logical relationship of the learning paths between the different subject areas and concepts. It serves as a service that stores and provides information, acting as a framework to allow both learners and instructors to structure or visualize the learning journey in a course syllabus and understand the dependencies between the different knowledge units.

The core functionality of this service is to be an archive. The instructor can access the frontend client page, access the available subjects, and see what is available. At the same time, the

instructor has the ability to fill the platform with additional content by adding the missing knowledge subjects to the platform in order to have available content in the platform to complete their skeletons and design the full learning journey of the course. Additionally, other services like the Worksheet and Learning Object Management service fetch regularly the content of the learning subjects service, mainly when a user wants to create a worksheet skeleton or to create a Learning Object to serve as tags in both of them.

The Learning Subject service serves a specific pedagogical role, which is to define the knowledge structure of a curriculum and organize the topics systematically. This provides for a clear curriculum design and assists him in creating the appropriate worksheet skeleton and avoiding learning errors by identifying learning gaps that must be addressed and may impede the course learning process.

4.2.8 Learning Object Management Service

The Learning Object Management Service is responsible for storing and categorizing the platform's pedagogical assets using metadata tags. It is also responsible for facilitating the retrieval and filtering of various types of pedagogical assets, such as text documents, videos, audio or voice recordings, and other online resources (e.g., questionnaires) from third-party platforms.

The service works as a learning objects archive that stores all the platform's assets and provides them to all instructors and content creators to create their own worksheet skeletons. The service usually communicates directly with the frontend client that requests to fetch available learning objects or specific subsets of learning objects when the client requests a learning object and provides filters with the request. When an instructor or a content creator attempts to create a learning object, the service communicates with the Learning Method, Learning Styles, and Learning Subjects to verify and tag the learning object with appropriate metadata before storing it. Furthermore, the service has direct communication with the Worksheet service when the instructor tries to create a new skeleton to assign the Learning Object to the appropriate dimensions, and again when the Worksheet service wants to generate a personalized worksheet fetches the skeleton objects and uses them to fetch the ranking and recommend the appropriate learning object. Finally, the User Profiling service retrieves the object when it is necessary to rank the learning object, allowing for the acquisition of object metadata, identification of similar Learning Objects, and calculation of the object ranking score.

The Learning Object Management service has a very critical and core pedagogical role. The role of the service is to manage the pool of Learning Objects, and provide to the instructors a pool of reusable, well-designed assets that they can use to meet their instructional goals. The objective is for the platform to be equipped with a curated collection of educator-validated learning resources that differentiate it from other online repositories and provide a scalable, dependable solution for high-quality training.

Chapter 5 - System Implementation

5.1 Technologies and Frameworks

The proposed educational platform consists of a set of technologies that enable the creation of a state-of-the-art platform. This section will present the set of the technologies and frameworks used in the platform implementation and justify the selection of the technologies and the main development tools. The platform's microservices-based design and adaptive instructional features necessitated the use of technologies that allow scalability, modularity, secure communication, efficient data management, and responsive interaction. Thus, the chosen stack was chosen to support the system's fundamental educational features, including student profile, worksheet creation, and personalized recommendation, as well as its technical structure.

5.1.1 Backend Technologies

The backend microservices adhere to a carefully considered architectural design tailored to the requirements of the platform. For service implementation, JavaScript and specifically Node.js, a cross-platform, open-source runtime environment, are widely used for building fast, reliable, and scalable server-side applications. To ensure correct software engineering principles implementation and consistent service quality, Clean Architecture was adopted as the core design pattern. This architecture partitions the codebase into four distinct layers (Domain, Application, Interface Adapters, and Frameworks), each with well-defined responsibilities and strict dependency constraints. This separation of concerns yields systems that are independently testable, maintainable, and adaptable, qualities that are particularly valuable over the extended lifespan of an educational platform. Moreover, this design streamlines the development process, facilitates knowledge transfer among developers, and reduces the onboarding overhead for new contributors.

Each service is designed to operate as a self-contained unit within the broader microservices architecture, which structures applications as collections of small, loosely coupled services, each responsible for a distinct business functionality. These services are independently deployable and scalable, communicating via lightweight REST APIs. All the intercommunication is subject to an authentication layer that enforces request integrity and access control. Incoming requests are routed through a dedicated API gateway, which serves as the platform's central orchestration and authorization point. Authorization is handled via JSON Web Tokens (JWT), a

stateless and secure mechanism for managing user permissions through cryptographically signed, self-contained tokens.

To minimize intercommunication dependencies and maximize platform reliability, each service maintains its own dedicated database. The choice of database technology is ruled by the specific data requirements of each service. Services that manage structured data, such as user profiling, learning objects, learning subjects, and authentication, employ PostgreSQL, a robust relational database management system. Contrarily, services that require flexible schemas and horizontal scalability, such as those handling learning styles, learning methods, and worksheets, utilize MongoDB, a document-oriented NoSQL database.

5.1.2 Frontend Technologies

The frontend application is developed using React, a declarative, component-based open-source JavaScript library, widely adopted for building dynamic and responsive user interfaces. The development environment is powered by Vite, a modern build tool that offers significantly faster cold starts and hot module replacement compared to conventional bundlers, making it particularly well-suited for large-scale React applications.

For application-wide state management, Redux is employed as a predictable, unidirectional data flow library that centralizes the application state and enforces a structured approach to state mutations. This ensures consistency across components and simplifies the debugging and tracing of state changes throughout the application lifecycle.

The user interface is constructed using Material UI, a comprehensive React component library that implements Google's Material Design specification. Material UI provides a consistent and accessible design system out of the box, accelerating development while maintaining visual coherence across the platform.

Finally, internationalization is handled via the i18next library, integrated through its dedicated React bindings. This enables the platform to support multiple languages through a structured key-based translation system, ensuring that the application remains accessible to a linguistically diverse user base, a critical requirement for an educational platform operating across different regional contexts.

5.1.3 DevOps Technologies

The platform adopts a continuous deployment pipeline to ensure that updates are delivered to the production environment in a controlled and automated manner. Source code is managed using Git, with the main branch serving as the source of truth of the production-ready codebase. Upon each commit to the main branch, a Jenkins pipeline is automatically triggered, orchestrating the full redeployment lifecycle without manual intervention.

The pipeline follows a structured sequence: Jenkins retrieves the latest revision of the affected service's codebase, rebuilds the corresponding Docker container image, and redeploys the updated container to the production environment. This containerized approach, enabled by Docker, ensures environment consistency across development and production stages, while isolating each service's runtime dependencies in accordance with the microservices architecture described previously.

5.2 Intercommunication

5.2.1 Worksheet creation

Worksheet creation is an important operational step for the platform since it connects the teacher's pedagogical decisions to the system's adaptive recommendation capabilities. When a teacher hits the worksheet skeleton creation page, the frontend app retrieves all the basic educational metadata required to identify the worksheet from the learning subjects service. The instructor then proceeds to set the structural characterization of the worksheet that relates to the learning style and educational goals of that specific worksheet skeleton after the frontend retrieves the necessary data from the learning style and worksheet service. By defining the skeleton's structural data, the system retrieves the filtered required learning objects that correspond to the skeleton information selected by the teacher. Following that, the instructor selects all the necessary learning and evaluation objects for all of the required bloom dimensions before proceeding to the final submission, in which the frontend sends the completed skeleton structure to the worksheet service, which evaluates and saves the worksheet.

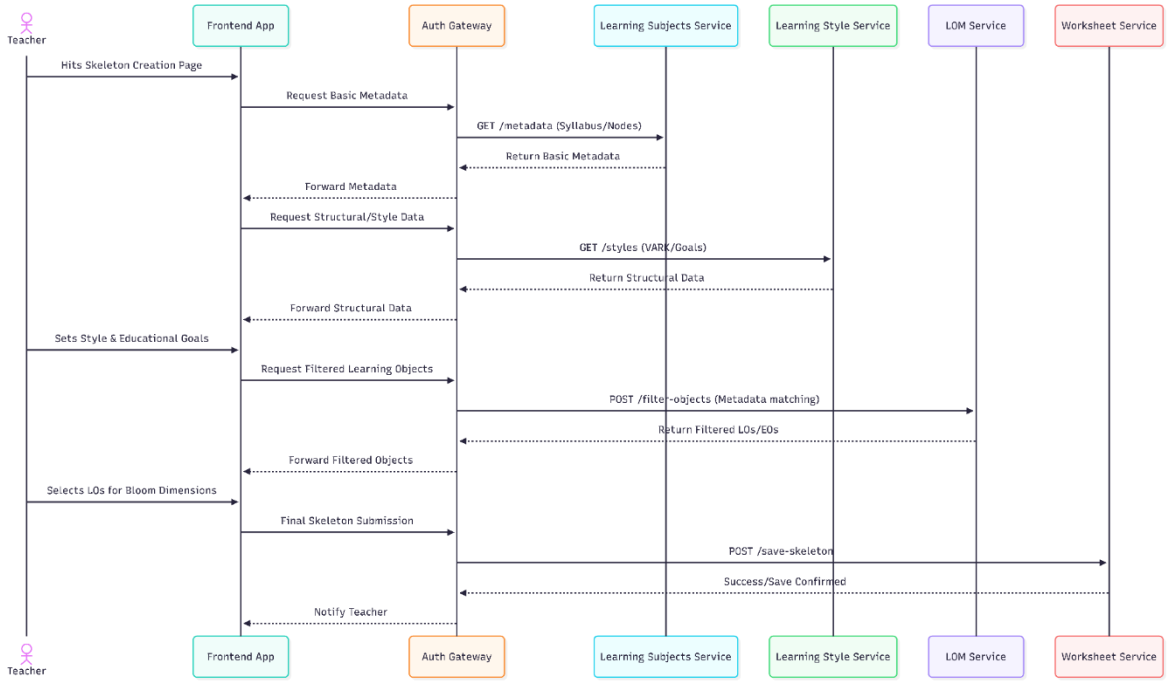


Figure 5.1. Worksheet creation Sequence Diagram

5.2.2 Worksheet generation

This workflow discusses the communication method used to create personalized worksheets. After a student chooses to generate a worksheet from a selected worksheet skeleton, the frontend confirms that the user has completed the relevant learning style questionnaire while retrieving the user profile from the user profiling service. If the user has previously completed the questionnaire, the frontend asks the worksheet creation service to build the tailored worksheet. The worksheet generating process begins at the worksheet service, where it retrieves the student's learning profile for the user profiling service and the worksheet skeleton learning objects from the appropriate service. Furthermore, the worksheet service requests that the learning objects be rated by the user profiling service, and when the worksheet receives the graded objects, it selects the items that best match the students. The produced worksheet is then saved, and the frontend gets informed to redirect the user to the personalized worksheet.

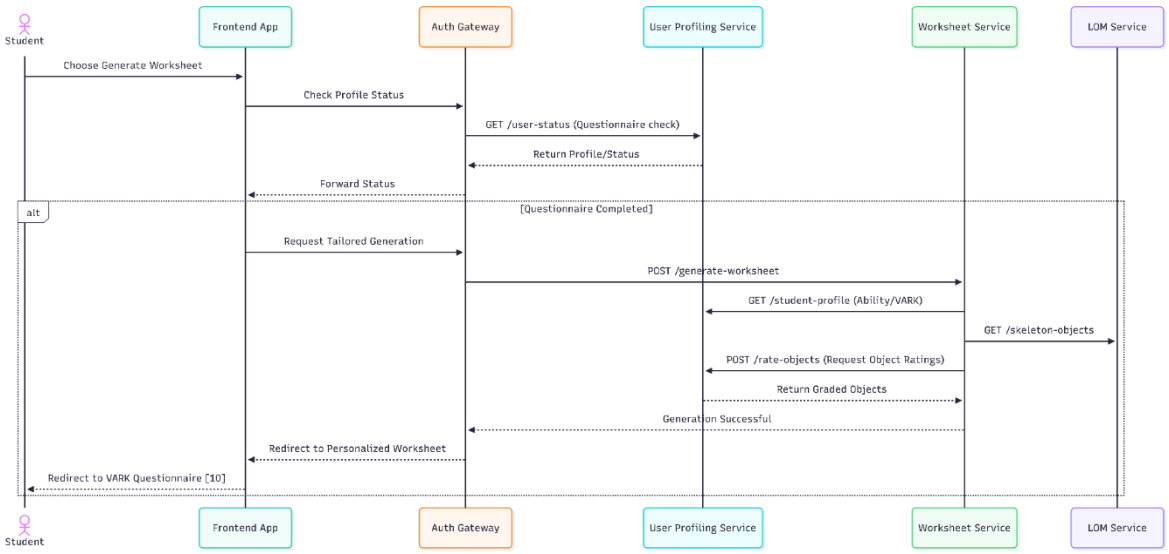


Figure 5.2. Worksheet generation Sequence Diagram

5.2.3 Worksheet execution

This workflow focuses on the inter-service communication that occurs during the worksheet execution. The process begins when the learner views an assigned worksheet via the frontend. The frontend obtains worksheet content from the worksheet service and then selects the necessary learning and assessment objects from the learning objects service. Following this, the learner begins executing the worksheet; throughout this stage, the platform captures all user action. The platform records the user's responses and ratings of its evaluation object on its step and saves the selected learning objects of its step when the user picks them, and all of them are recorded through a request to the worksheet service during the worksheet's execution. Finally, after the worksheet is finished, the user sends the final version with all of the responses and the final satisfaction rating of the worksheet to the worksheet service to save them. This method ensures that worksheet interaction is continuously monitored and execution data is saved for later evaluation.

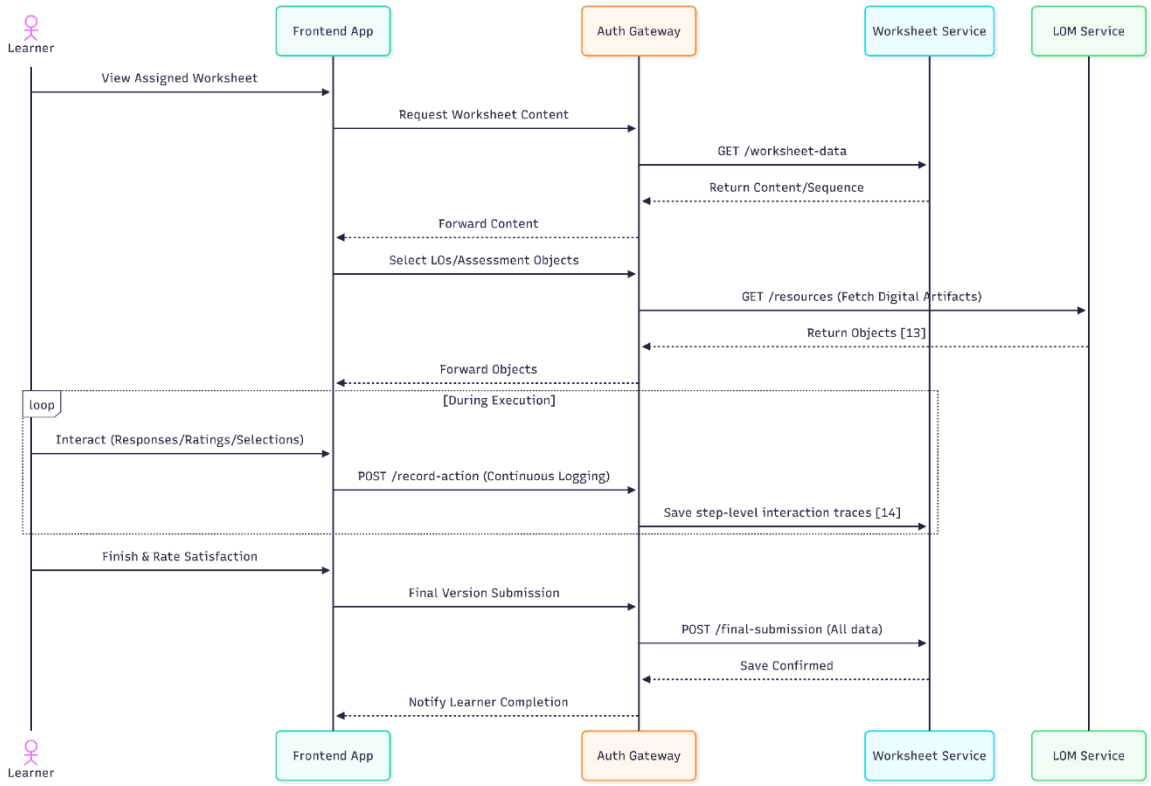


Figure 5.3. Worksheet Execution Sequence Diagram

5.2.4 Worksheet grading and profile update

This workflow outlines the communication procedure that occurs once the worksheet is completed. The flow begins when the teacher begins the review of a previously submitted worksheet. The teacher goes to the completed worksheet page on the frontend application, and the frontend retrieves the completed worksheet from the worksheet service. The Teacher then grades the entire worksheet and submits it to the worksheet service. After the grading is submitted, the worksheet service records the results and initiates the profile update. To update the learner's profile, the worksheet service sends all of the necessary information about the learner's performance, preferences, and satisfaction to the profiling service, and the service updates the learner's learning profile. This workflow closes the adaptive cycle of the platform by connecting learner performance with future personalization decisions.

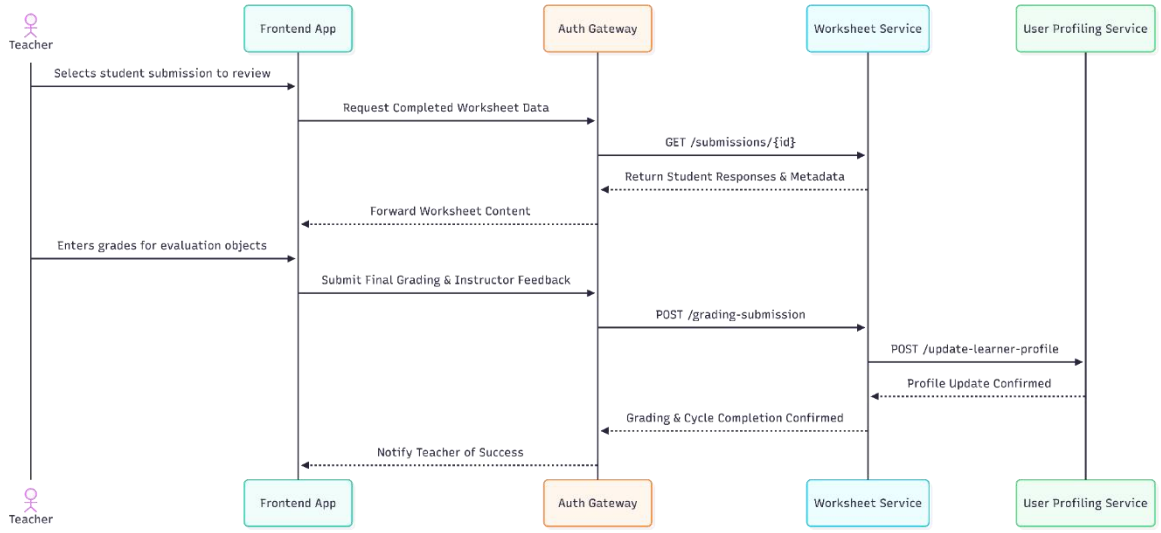


Figure 5.4. Worksheet grading and Profile update Sequence Diagram

Chapter 6 - Results & Discussion

6.1 Results

The implementation phase of this research has produced a functional, microservices-based educational platform with a frontend developed using React and Material UI.

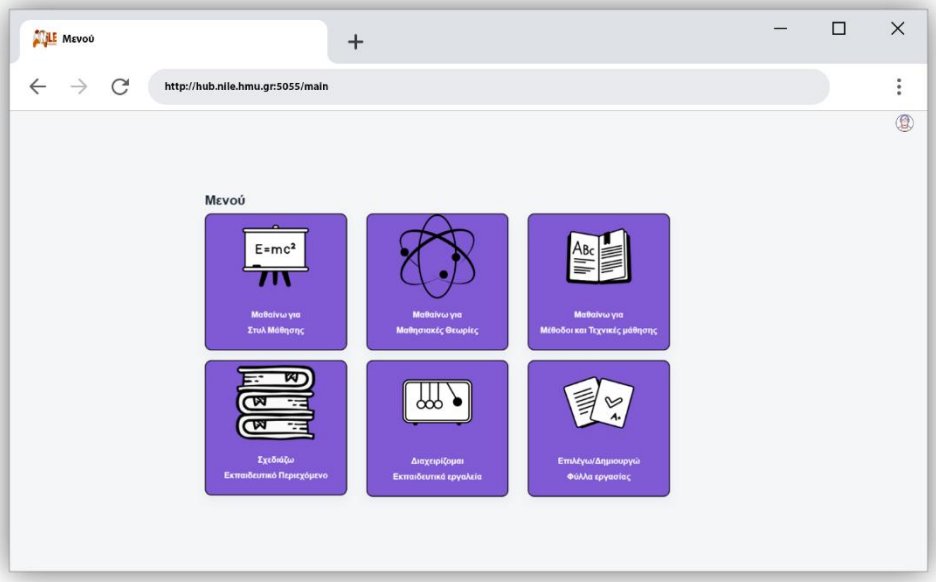


Figure 6.1. Main Menu

The user experience is centered around a **Main Menu** (Figure 6.1) which serves as the primary navigation hub, offering six distinct modules categorized into pedagogical knowledge (Learning Styles, Theories, and Methods) and administrative orchestration (Educational Content Design, Tool Management, and Worksheet Creation).

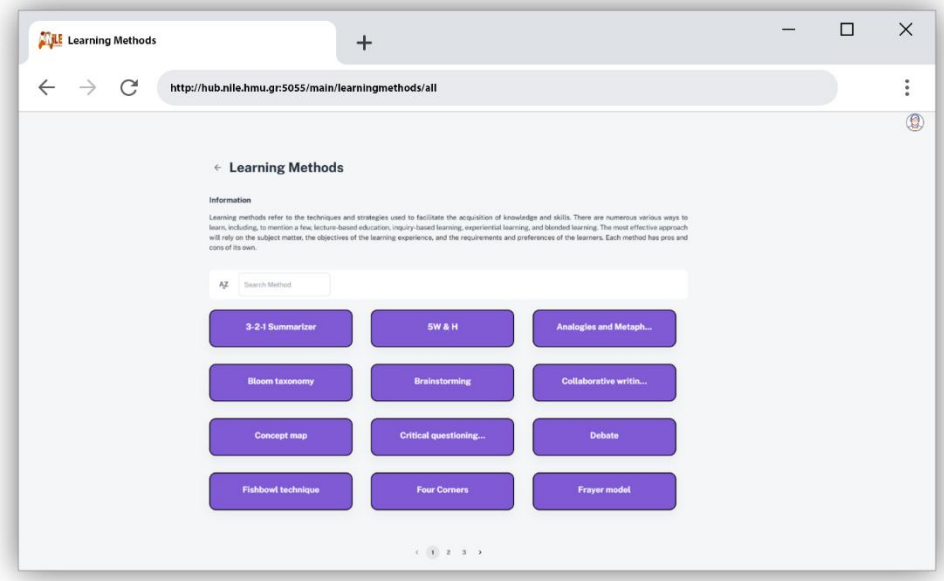


Figure 6.2. Learning Methods

To support the teacher's role as a mentor, the platform includes dedicated repositories for **Learning Methods** (Figure 6.2), which provide structured strategies such as "Brainstorming" or "Concept Maps," and informational modals detailing **Learning Styles** like the Felder-Silverman model (Figure 3_4) and **Learning Theories** such as Behaviorism (Figure 6.3).

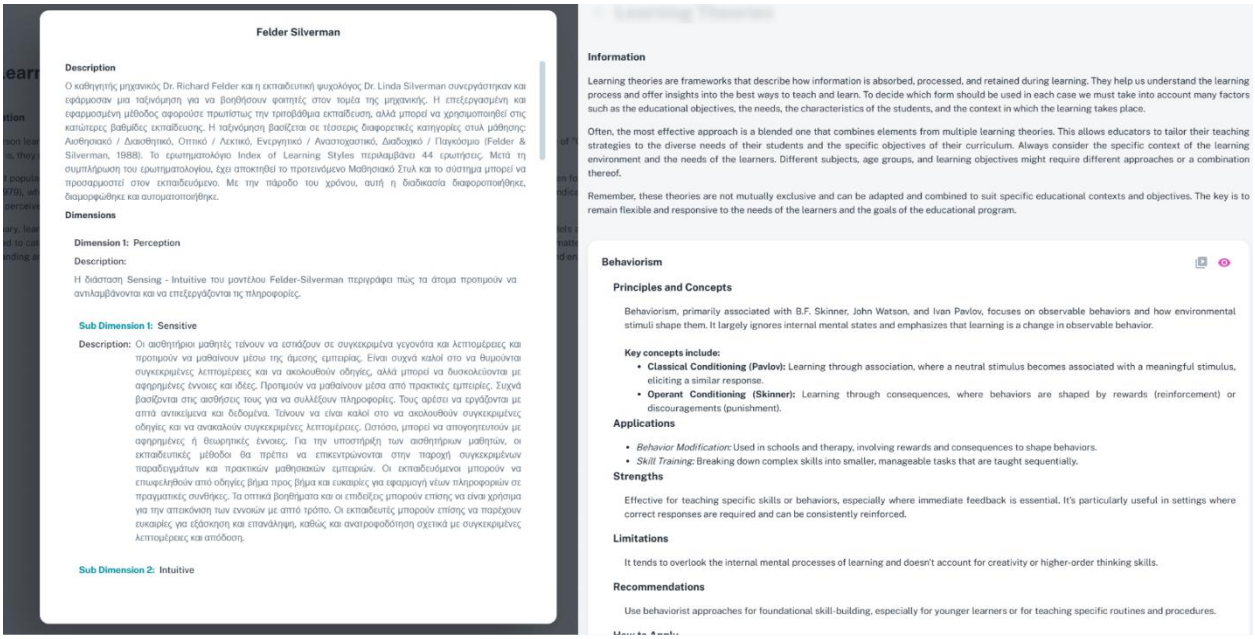


Figure 6.3. Learning Styles and Theories 2

The administrative capabilities of the platform are further demonstrated through the Educational Resources interface (Figure 6.4), where stakeholders can manage institutional data, such as school names and educational levels.

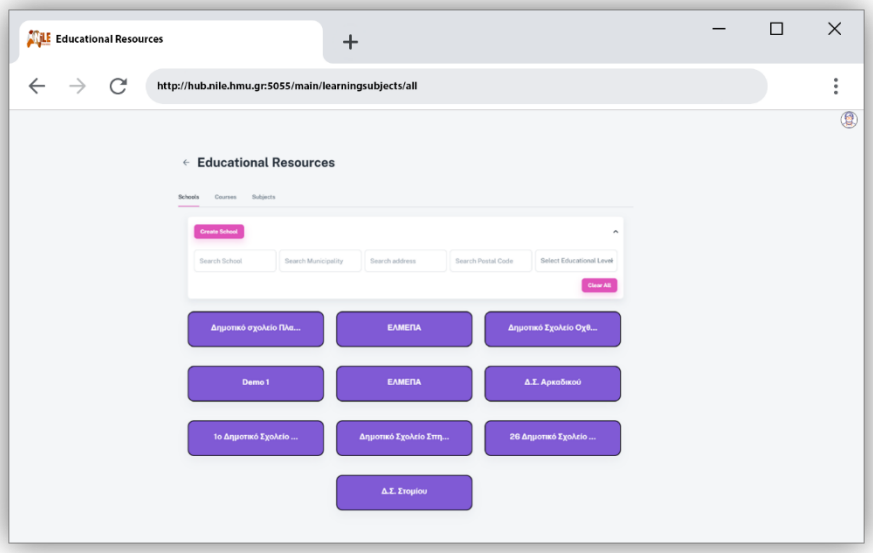


Figure 6.4. Educational Resources

As the central piece of the recommendation engine is the Learning Objects repository (Figure 6.5), which displays a comprehensive list of pedagogical assets tagged with essential metadata including language, difficulty, format, and estimated completion time.

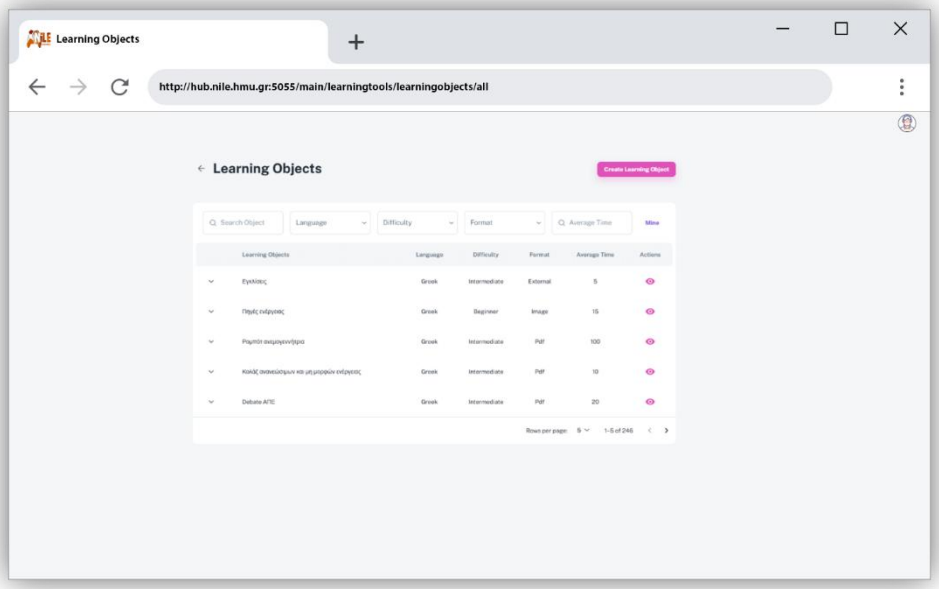


Figure 6.5. Learning Objects

When adding new content, users are presented with Learning Object Creation Options (Figure 6.6) for various media types such as video, sound, text and external sources from third party platforms like wordwall.net or wayground.com.

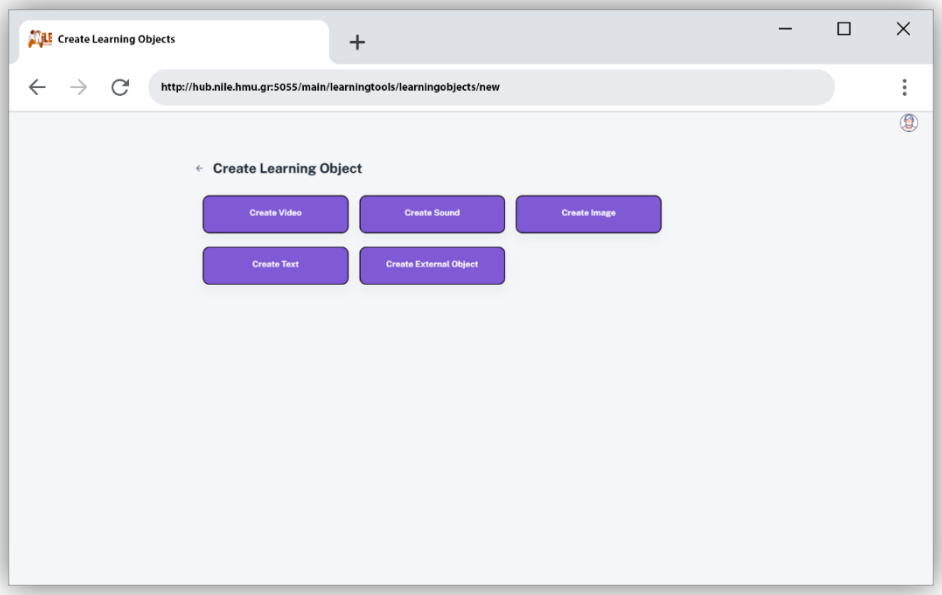


Figure 6.6. Create Learning Object options

For example, Create Text workflow illustrates the granular level of control provided to content creators, who must not only provide the learning object and input titles and descriptions (Figures 6.7)

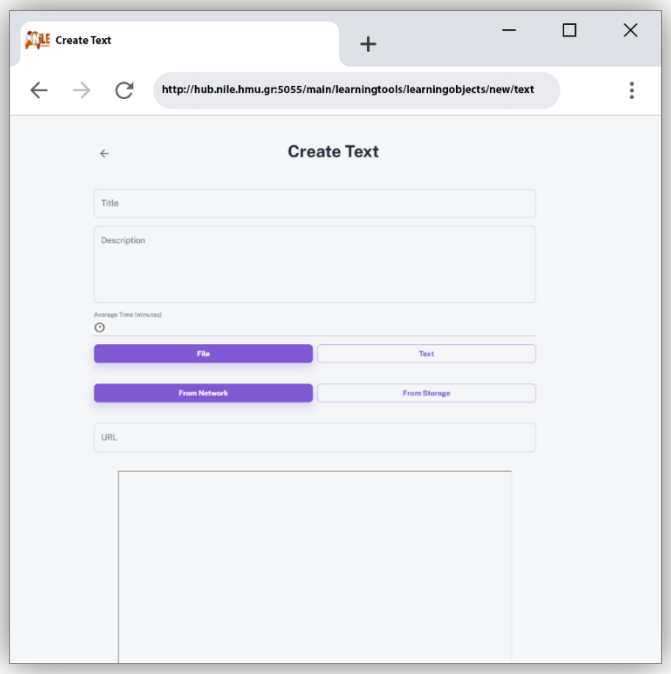


Figure 6.7. Create Text Learning Object Step 1

but also apply specific Tags for Bloom's Taxonomy dimensions, the 4Cs, and intended learning styles to ensure the recommendation algorithm can effectively process the asset (Figures 6.8).

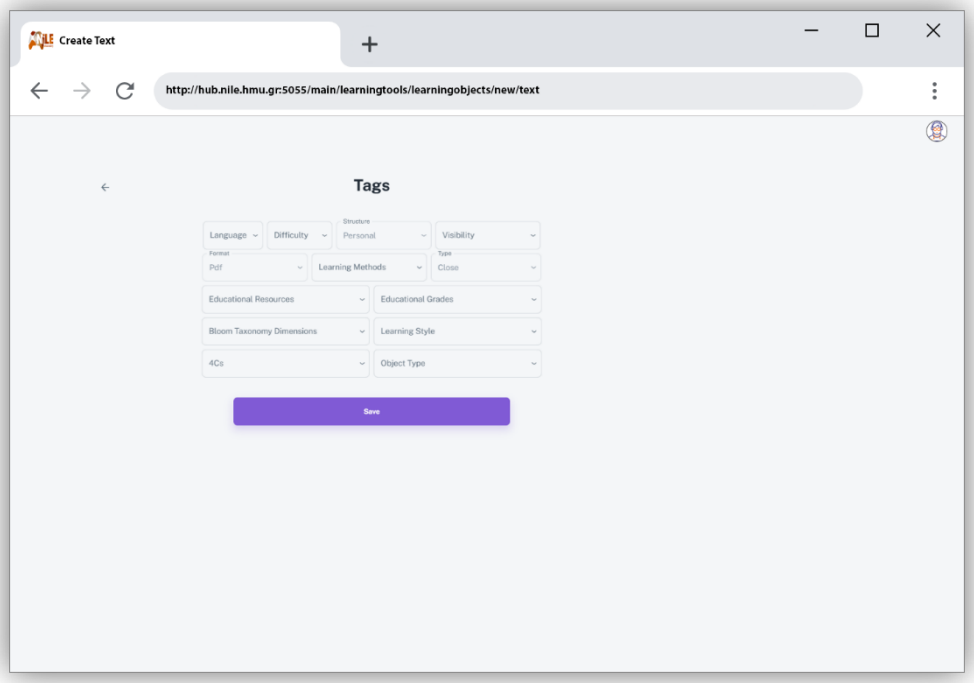


Figure 6.8. Create Text Learning Object Step 2

The core orchestration feature for educators is the management of Worksheet Skeletons (Figure 6.9), which provides a searchable list of curriculum-aligned skeletons. The platform utilizes a structured six-step wizard to guide teachers through the Skeleton Creation process:

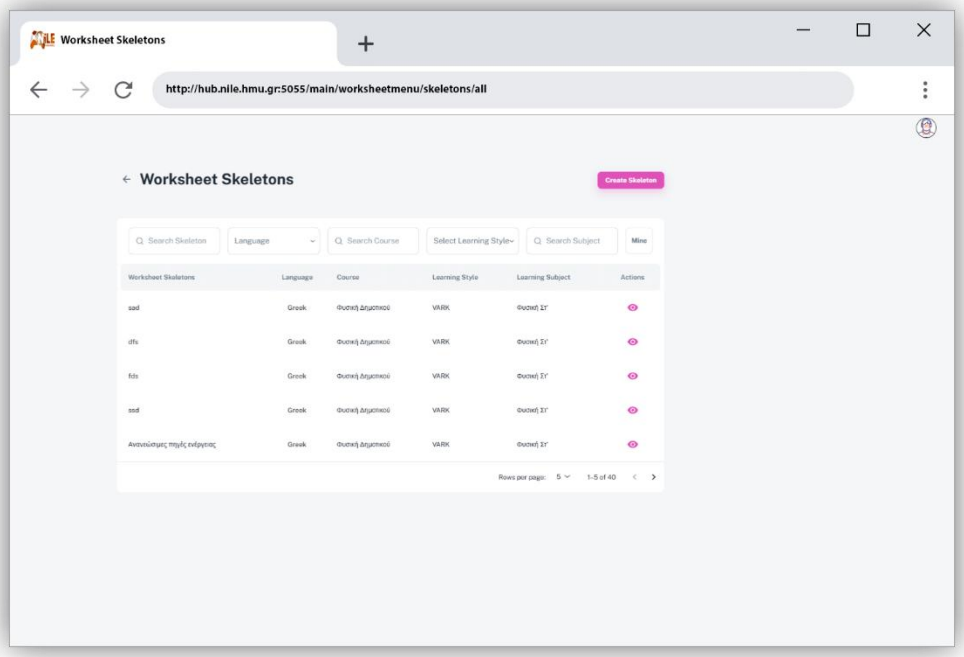


Figure 6.9. Worksheet skeletons

At Step A, there's a Basic Information form (Figure 6.10), which provides the foundational context, such as the subject, grade level, and school.

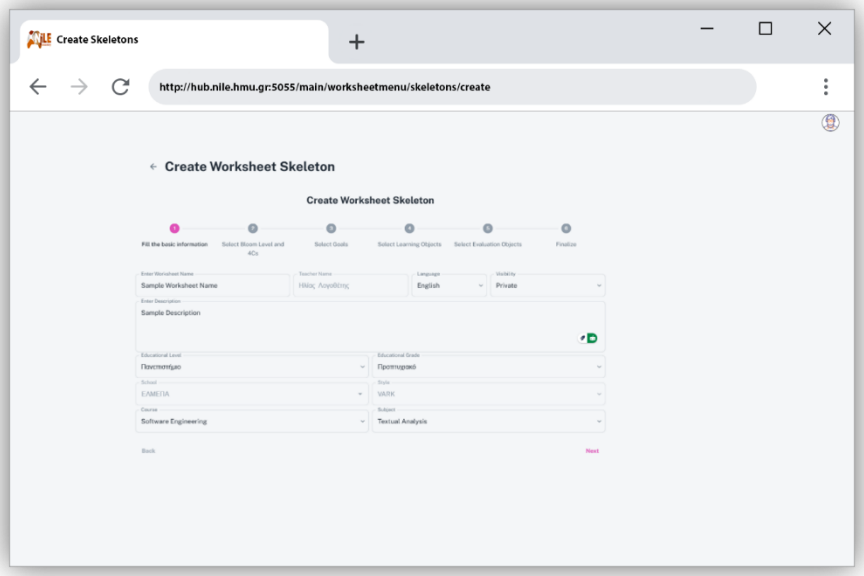


Figure 6.10. Create Skeleton Step A

Moving on to **Step B**, we observe the **Bloom Level and 4Cs** form (Figure 6.11), which allows the teacher to describe the target cognitive complexity and the specific 21st-century skills that the worksheet is designed to develop.

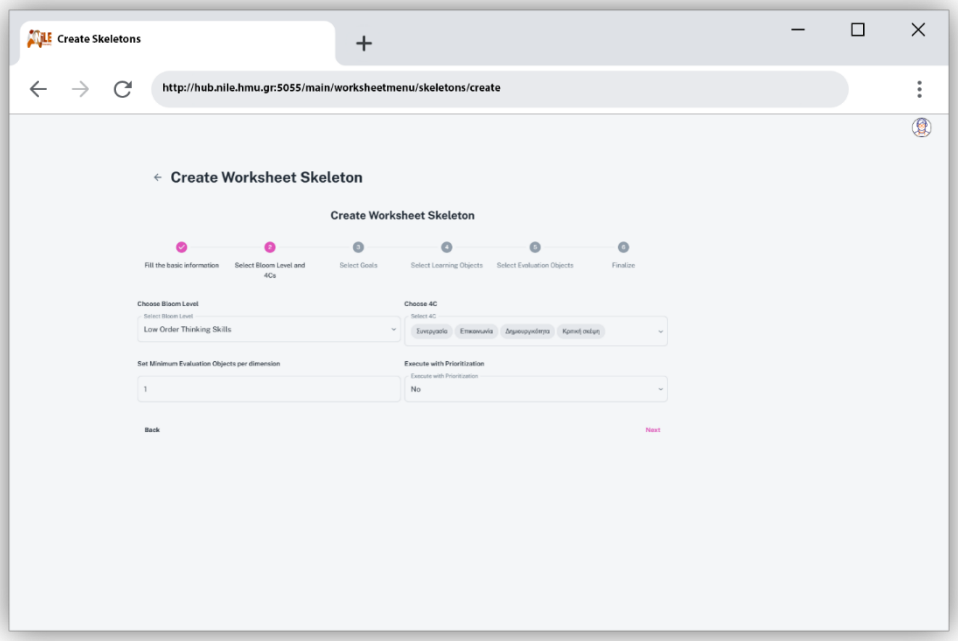


Figure 6.11. Create Skeleton Step B

Furthermore, at Step C, we encounter the Goals Selection form (Figure 6.12), which uses an interactive interface to allow teachers to select specific verbs related with Bloom's dimensions (for example, "Recognizing," "Naming").

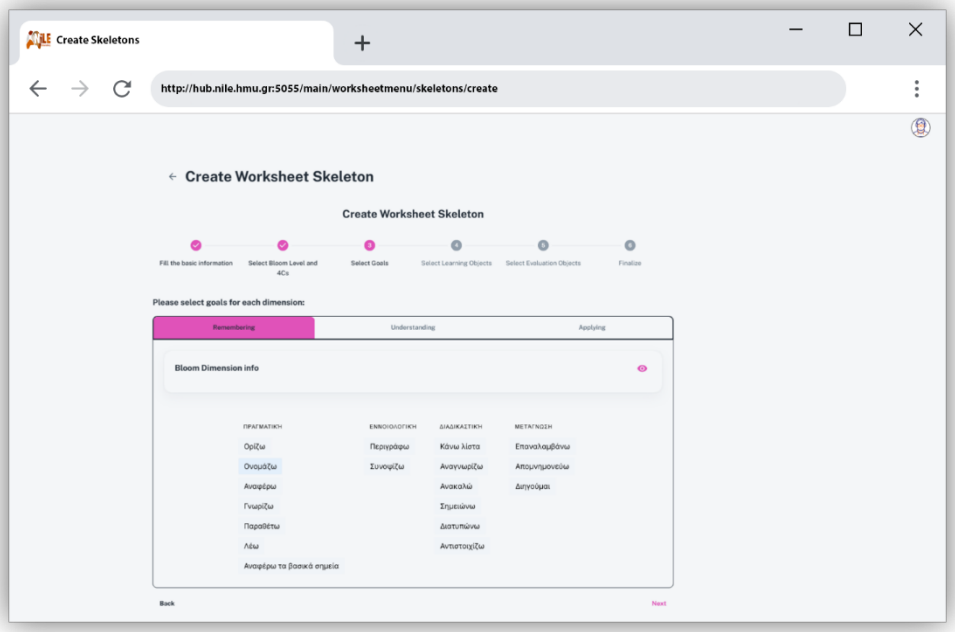


Figure 6.12. Create Skeleton Step C

Furthermore, at Step D, we reach the Learning Object Selection form (Figure 6.13), which allows the teacher to select specific instructional materials that correspond to the previously stated goals and difficulty levels.

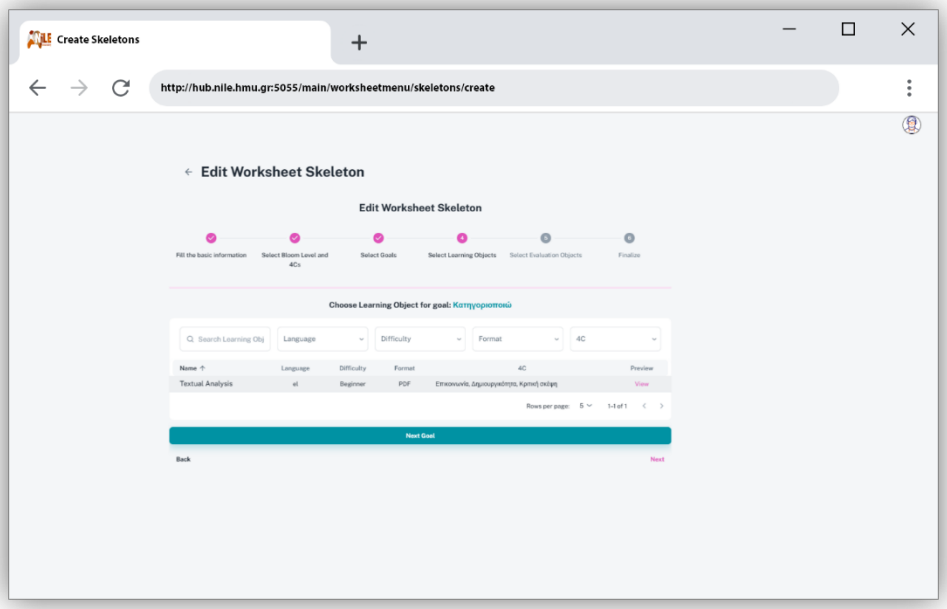


Figure 6.13. Create Skeleton Step D

Similarly, in Step E, we are presented with the Evaluation Object Selection form (Figure 6.14), which concentrates on the assessment component and requires at least three evaluative objects per dimension to enable system-driven personalization.

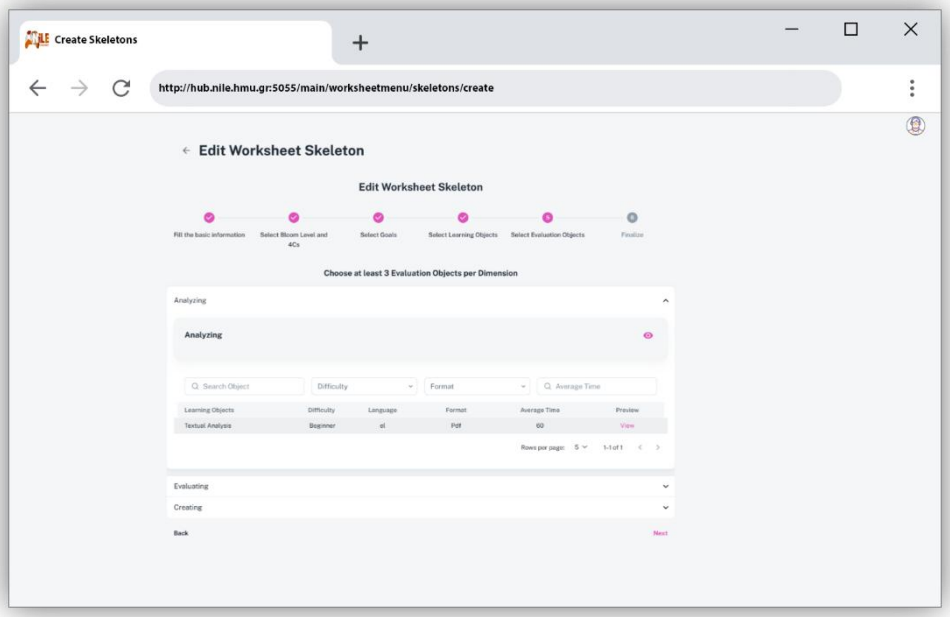


Figure 6.14. Create Skeleton Step E

At Step F, the Finalization form (Figure 6.15) summarizes the complete setup, displaying the mapped relationship between pedagogical goals, learning objects, and evaluation tasks.

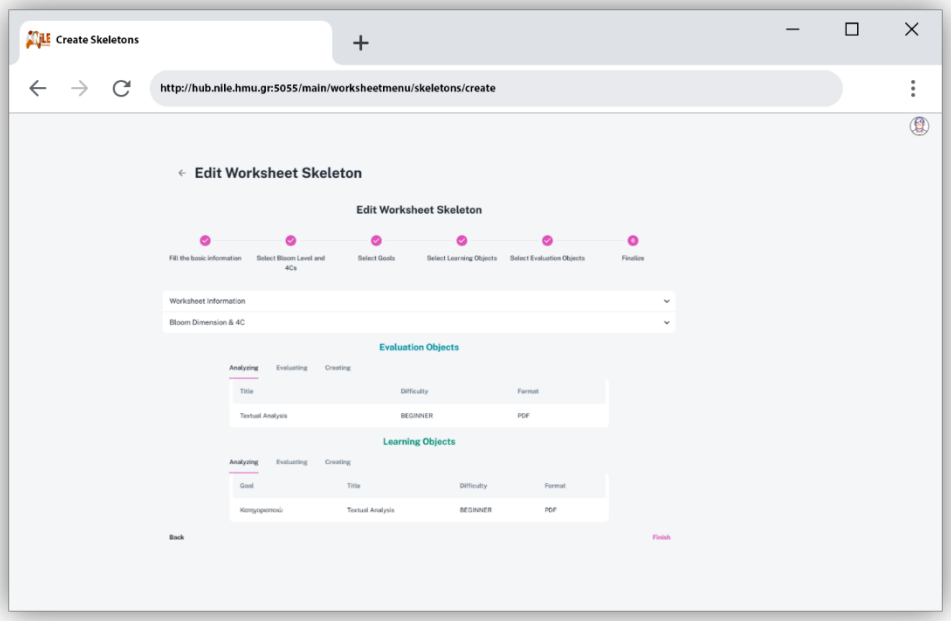


Figure 6.15. Create Skeleton Step F

Finally, the Edit Worksheet Skeleton interface (Figure 6.16) demonstrates the platform's flexibility, allowing instructors to revisit and refine existing skeletons to better suit evolving curriculum needs or student performance data. Together, these interfaces provide a comprehensive environment that balances automated personalization with teacher-driven pedagogical governance.

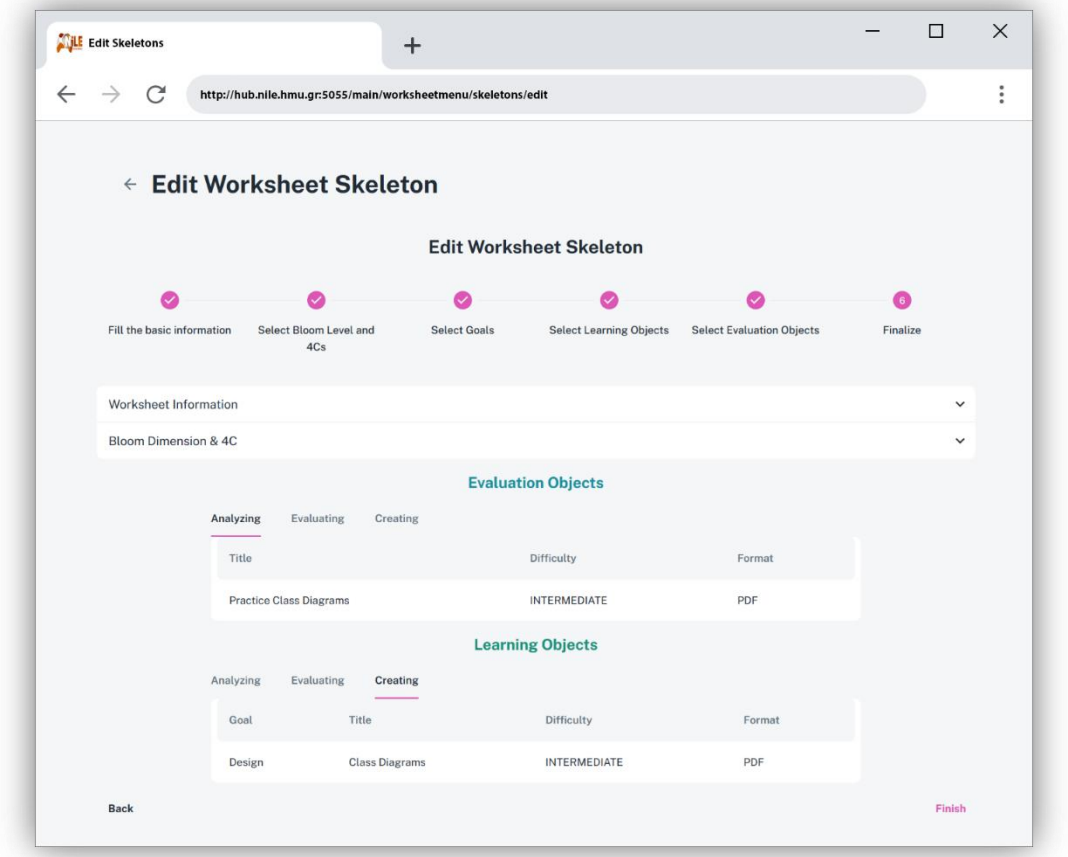


Figure 6.16. Edit Skeleton Final screen

6.2 Discussion

The results of this thesis demonstrate that the platform effectively addresses the "one-size-fits-all" limitation of conventional learning systems, which often fail to account for the diverse cognitive and interpersonal needs of modern classrooms. By moving toward a learner-oriented paradigm, the platform ensures that instructional materials are tailored to individual strengths and preferences rather than forcing all students through a fixed, identical sequence.

Support for Personalized and Blended Learning The core contribution of this work is its ability to generate adaptive worksheets that reflect the learner's unique profile. This is achieved while keeping the teacher in control; instead of a "black box" automation, the system acts as an "intelligent teaching assistant". Teachers define the worksheet structure, curate the learning objects, and establish the pedagogical metadata, ensuring that the system's recommendations align with the overarching curriculum goals. Furthermore, the platform's design inherently supports blended learning, as it allows students to transition seamlessly between in-class physical tasks and home-based digital activities, providing a cohesive learning path across different environments.

Technically, the platform takes a hybrid recommendation technique that blends content-based and collaborative filtering. By combining learner profiles, performance data, and peer similarity, the system creates pathways that are both accurate and educational. A significant component is the system's management of the cold-start problem; by using early VARK questionnaires, the platform may construct a baseline profile for new learners before enough performance data is available to drive collaborative filtering. Crucially, these profiles are dynamic rather than static; when the learner completes assignments and receives grades, the system changes their profile in real time, allowing personalization to improve as the student progresses.

Scalability and Practical Contribution From a practical aspect, the platform improves scalability by providing a reusable repository of learning objects and worksheet templates. Metadata standards (such as IEEE LOM) enable teachers to share and adapt high-quality pedagogical artifacts, saving the manual labor often necessary for large-scale personalization.
Despite these achievements, the platform has found many limitations. One significant constraint is resource dependency. The recommendation engine's performance is heavily reliant on a large, high-quality archive of learning objects and correct metadata labeling by content authors. Another restriction to consider is data sparsity: while questionnaires help to alleviate the cold-start issue, the system still needs constant student interaction to improve the quality of its collaborative filtering models over time. Last but not least, Technical Coordination is a critical constraint that defines the microservices architecture, which, while scalable, introduces challenges with data consistency across distributed databases, necessitating robust asynchronous communication to maintain the integrity of the learner's profile.

Chapter 7 - Conclusions and Future Work

7.1 Conclusion

The development of the proposed platform targets the critical challenges of traditional "one-size-fits-all" educational approaches, which frequently overlook the various interpersonal and cognitive requirements of today's students. This master's thesis has shown how pedagogical frameworks, like the Revised Bloom's Taxonomy and the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity), can be methodically incorporated into a technical environment to promote higher-order thinking by shifting to a learner-oriented paradigm.

The platform's microservices-based design, which is divided into seven autonomous modules, provides a strong and scalable foundation for fault tolerance and technological flexibility. The hybrid recommendation system, which is at the heart of this design, successfully synthesizes personalized learning paths using multi-criteria signals such as VARK learning styles, prior performance, and peer similarity. This study makes a substantial contribution in overcoming the "cold-start" problem by using pedagogical initialization questions, which allow for accurate recommendations from a learner's first interaction with the system.

Furthermore, the platform successfully redefines the role of the educator from a manual content creator to a pedagogical orchestrator. Teachers maintain instructional control over the curriculum via worksheet skeletons, while the system handles the labor-intensive task of task-level customization. This transition not only decreases administrative workload, but also enables educators to focus on mentorship and tailored interventions for children with special learning needs. In essence, the platform offers a cutting-edge solution that combines artificial intelligence with human-driven pedagogical governance to improve the overall effectiveness of blended learning.

7.2 Future Work

While the existing platform provides a good foundation for adaptive learning, there are still various opportunities for further improvement. The combination of Generative AI and Large Language Models (LLMs) could be used to shift from rule-based metadata tagging to content-aware, dynamic profiling that provides more detailed instructive insights.

Technical evolution should also prioritize improved interoperability, allowing the platform to function as a hub for external educational resources and specialized third-party evaluation tools via open APIs. Finally, longitudinal empirical research in varied classroom settings will be required to assess the platform's long-term impact on academic resilience and the sustained development of 21st-century abilities.

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Appendix A - Requirements

This appendix contains the full system requirements specification for the proposed adaptive blended learning platform. Each requirement is written in a structured format that includes the identifier, title, description, appropriate user roles, prerequisites, expected post-condition, main success scenario, and exceptions.

The requirements are divided into two groups. The functional requirements (FR1-FR27) specify the platform's unique behaviors and capabilities, which include user and role management, learner profiling, curriculum administration, content authoring, worksheet generation, learner engagement, and the adaptive feedback loop. The non-functional requirements (FR28-FR45) specify the quality qualities that govern how those capabilities are supplied, including pedagogical quality, usability, dependability, scalability, security, data integrity, and deployability.

Section 3.1.2 of Chapter 3 provides a consolidated overview of all requirements, including their title, description, use case diagrams and classification. The extensive forms in this appendix serve as a comprehensive specification reference.

A.1 Functional Requirements

User and Role Management

Table A. 1 Support for Distinct user Roles Requirement

A/A	1
Title	Support for Distinct user Roles
Description	The platform must offer unique user roles, such as student, teacher, content developer, educational expert, and administrator, to reflect the system's differentiated pedagogical and administrative workflows.
Roles	All

Prerequisites	-
Status after completion	The platform supports multiple types of users. Each user can visit the platform and register with a unique roll that suits the type of the user
Main Success Scenario	• The user visits the platform's landing page. • The user proceeds to the signup page. • The user chooses which role they want to register under. • The user enters the required information for registration. • The user submits a registration form. • The platform redirects the user to the login page.
Exceptions	• If the user inputs any of the required registration information improperly, the platform alerts the user that the data are invalid and that they need to be audited. • The admin registration is completed always by the platform owners

Table A. 2 Role based Access Control Requirement

A/A	2
Title	Role based Access Control
Description	The platform must enforce role-based permissions so that each stakeholder can only access functions and data that are relevant to their duties, ensuring controlled use of platform services and content.
Roles	All
Prerequisites	-

Status after completion	Depending on their responsibilities, each user has distinct permissions, which allow them to access particular pages and carry out actions that are appropriate for their positions.
Main Success Scenario	• Visit landing page of the platform • Visit the login in page • Login and access the pages and perform the permitted actions of the user role
Exceptions	• In the event that the user enters faulty credentials, the platform informs the user via an alert box that the credentials are valid

Table A. 3 Administrative Management Requirement

A/A	3
Title	Administrative Management
Description	The platform shall allow administrators to manage all the content of the platform and allow them to delete content in order to support secure and organized system administration.
Roles	Admin
Prerequisites	• The administrator should be logged in
Status after completion	The administrator has the ability to edit and delete any content on the platform.

Main Success Scenario	• The administrator logs in the platform • The administrator visits the newly educational content in the platform • The administrator reviews the content • The administrator has the ability to prohibit unwanted content and amend or remove it.
Exceptions	• In the event that an administrator wants to delete an learning object associated with a worksheet the administrator can not manually delete an object and needs to request the deletion to the platform owners

Learner Profiling and Adaptation Setup

Table A. 4 Initial Learner Profile Creation Requirement

A/A	4
Title	Initial Learner Profile Creation
Description	During the first use of the platform, an initial learner profile is created to serve as the foundation for adaptive personalization. This initialization of the profile should be done using pedagogically authorized questionnaires to which the user should respond upon encountering a learning style.
Roles	Students
Prerequisites	• The user should be logged in
Status after completion	The platform has questionnaires that can be answered and use them for the profile initialization.

Main Success Scenario	• The user visits for the first time a worksheet skeleton that has been shared by the teacher. • The user requests to generate a personalized worksheet. • The platform checks if the user profile is initialized for that specific learning style defined by the worksheet skeleton. • The platform redirects the user to the learning style questionnaire • The user responds the questionnaire • The platform initializes the student profile • The platform generates the worksheet for the learner
Exceptions	

Table A. 5 Collection of Learner Information Requirement

A/A	5
Title	Collection of Learner Information
Description	The platform will collect demographic and educational data essential to learner identification and classification, such as grade level and other profile characteristics required for adaptation.
Roles	Student
Prerequisites	• The user should be logged in
Status after completion	When a user logs in for the first time, the platform requires them to provide the necessary demographic information.

Main Success Scenario	• The learner logins to the platform • The learner fills the demographic info and updated the profile info • Then the user moves to navigate to the rest of the platform pages
Exceptions	• When a user misses an input or enters inaccurate data, saves the profile, and attempts to leave the profile page, the platform determines if the learner has completed the profile demographic information and redirects the user to the profile page until the profile information is completed.

Table A. 6 Dynamic Profile Update Requirement

A/A	6
Title	Dynamic Profile Update
Description	Following worksheet completion, the platform will update the learner profile with performance, feedback, and behavioral data to ensure that future recommendations are tailored to the learner's current needs.
Roles	Student
Prerequisites	• The user should be logged in
Status after completion	The platform updates the learning profile of the learner each time a user completes the worksheet and the Teacher evaluates the worksheet.

Main Success Scenario	• The learner submits in a worksheet that includes all of the answers and an enjoyment rating for both the evaluation items and the entire worksheet. • The teacher examines the worksheet, evaluates the student's responses, and submits the completed worksheet evaluation. • The platform saves the response to the evaluation scores. • Based on student performance score and satisfaction ratings, the platform updates the learner's learning profile.
Exceptions	-

Table A. 7 Storage Adaptive Learner Data Requirement

A/A	7
Title	Storage Adaptive Learner Data
Description	Following worksheet completion, the platform will update the learner profile with performance, feedback, and behavioral data to ensure that future recommendations are tailored to the learner's current needs.
Roles	Student, Teacher
Prerequisites	• The user should be logged in
Status after completion	The platform stores all the behavioral, performance and satisfaction ratings of the user on submission and evaluation of a worksheet.

Main Success Scenario	• The learner submits in a worksheet that includes all of the answers and an enjoyment rating for both the evaluation items and the entire worksheet. • The platform stores all the answers of the user, the learning objects that the learner decided to read and the user satisfaction ratings on the submission of the worksheet. • The teacher examines the worksheet, evaluates the student's responses, and submits the completed worksheet evaluation. • The platform saves the response and the evaluation score. • Based on student performance and satisfaction, the platform updates the learner's learning profile.
Exceptions	

Curriculum, Learning Content, and Pedagogical Resource Management

Table A. 8 Learning Subject Management Requirement

A/A	8
Title	Learning Subject Management
Description	The platform shall support the creation, storage, and management of learning subjects required for worksheet preparation and curriculum selection.
Roles	Educational Expert
Prerequisites	• The user should be logged in

Status after completion	The Educational Expert can add new learning subjects and update the existing records.
Main Success Scenario	• The Educational Expert visits the page the displays the learning subjects • The expert evaluates the existing learning subject • The expert decides which learning subject needs to be updated and updates the content
Exceptions	• In case the educational expert misses to update any required filled or fills out the form with invalid data the platform shows to the user a warning message to audit the form and resubmit.

Table A. 9 Hierarchical Curriculum Representation Requirement

A/A	9
Title	Hierarchical Curriculum Representation
Description	The platform must show curriculum structure hierarchically, including syllabus, and subject area, to assist teachers in making structured instructional decisions.
Roles	ALL
Prerequisites	• The user should be logged in
Status after completion	The platform contains and displays the required learning methods, learning subject material required for a hierarchical curriculum and to help the Teacher to design the curriculum and make the appropriate worksheet skeletons.

Main Success Scenario	• The Teacher visits the Learning Methods page and reads all the available pedagogical info • The Teacher visits page Learning Subjects page and reads all the available pedagogical info • The Teacher evaluates the acquired knowledge • The Teacher visits the worksheet skeleton creation page and creates worksheet skeleton that follow the curriculum design
Exceptions	-

Table A. 10 Support Digital and Non-Digital Tools Requirement

A/A	10
Title	Support Digital and Non-Digital Tools
Description	The platform must enable both digital and non-digital learning resources in order to function in blended learning environments that include both classroom and home settings.
Roles	Teacher, Student
Prerequisites	• Both Teacher and Learner should be logged in
Status after completion	The platform allows the generated worksheet to have empty answer submission when the Teacher requires a physical in class submission.

Main Success Scenario	• The Teacher shares a worksheet • The Teacher requests that the first level bloom evaluation object answer be a physical in-class submission. • The Learner access the worksheet and starts or continues the execution of the worksheet • The learner skips the answer or comments in the answer field that has submitted the answer in a physical form.
Exceptions	•

Table A. 11 Learning Object Metadata Management Requirement

A/A	11
Title	Learning Object Metadata Management
Description	The platform must contain metadata for learning objects, such as subject, difficulty, grade level, and other descriptive properties used for filtering and recommendation.
Roles	Teacher, Content Creator, Educational Expert
Prerequisites	• The user should be logged in
Status after completion	The platform requires metadata tagging when creating each learning object for a variety of information categories such as learning subject, difficulty, grade level, and so on.

Main Success Scenario	• The user visits the learning objects page • The user selects to create learning object action • The user selects the type of the learning object (ex. a video learning object) • The user inputs the basic learning object info like the link or the file that represents the objects, the name, the duration and the description • The user characterizes the learning object by marking it with the educational information metadata. • The user submits the final version of the learning object.
Exceptions	• When a user attempts to edit or create a learning object and misses a field or enters invalid data on the next step button, the platform displays a notification informing the user that the data must be audited before proceeding.

Table A. 12 Cognitive Level Classification of Activities Requirement

A/A	12
Title	Cognitive Level Classification of Activities
Description	The software will classify learning activities and learning objects based on cognitive level, ensuring that adaptive worksheet production follows an educationally coherent progression.
Roles	ALL
Prerequisites	-
Status after completion	The platform allows for the filtering of learning objects, and the recommendation system uses the tagged cognitive level to deliver appropriate adaptive worksheet recommendations.

Main Success Scenario	• The Teacher/Educational Expert creates worksheet skeleton • The user tags with metadata the worksheet skeleton • The system filters the available metadata by comparing the learning objects metadata and skeleton • The user selects objects that serve better the educational goals from the list provided
Exceptions	-

Content Authoring, Validation, and Pedagogical Governance

Table A. 13 Content Creation Requirement

A/A	13
Title	Content Creation
Description	The platform should enable users with the necessary permissions to create content. Users should be able to create and update learning objects, subjects, and methods to expand the platform archive and address pedagogical demands and curriculum progression.
Roles	Content Creator, Educational Expert, Teacher
Prerequisites	• The user should be logged in

Status after completion	• The platform should allow Content Creators to create learning objects and extend the learning objects archive. • The platform should allow Educational Experts to update the knowledge base for learning methods and disciplines, create new learning objects, as well as generate new worksheet skeletons or update those that they have already made. • The platform should allow teachers to add new learning subjects and learning objects that the platform does not already cover in order to adhere to their curriculum, as well as build new worksheet skeletons or update existing ones.
Main Success Scenario	Main scenario?
Exceptions	-

Teacher Classroom and Worksheet Management

Table A. 14 Student Classroom Worksheet Sharing Requirement

A/A	14
Title	Student Classroom Worksheet Sharing
Description	The platform will enable teachers to share worksheet skeleton with students in their classrooms, allowing for individualized worksheet generation within a course environment.
Roles	Teacher, Student
Prerequisites	• Both Teacher and students should be logged in

Status after completion	The platform lets you share the worksheet's unique URI or title, making it easier for learners to obtain the worksheet skeleton quickly.
Main Success Scenario	• The Teacher visits the worksheet skeleton that wants to share with his students • The Teacher copies the URI of the worksheet skeleton or the unique title • The Teacher shares manually the unique identifier with students
Exceptions	• If the student is not logged in and attempts to use the URI to access the worksheet skeleton, the platform redirects the user to the login page.

Table A. 15 Selection of Predefined Worksheets Requirement

A/A	15
Title	Selection of Predefined Worksheets
Description	The platform shall allow teachers to select predefined generic worksheets provided in the platform archive as a basis for instructional adaptation and reuse.
Roles	Teacher, Educational expert
Prerequisites	• The user should be logged in • The worksheet should not be creation of the same user

Status after completion	The platform allows a Teacher to preview all the public worksheet skeletons and select and copy existing worksheets to share with classroom students.
Main Success Scenario	• Teacher visits the worksheet skeletons page • Teacher selects the public skeleton that matches the classroom curriculum • Teacher selects the copy button • The platform creates a copy of the worksheet and redirects the teacher personal worksheets page
Exceptions	-

Table A. 16 Instructional context characterization Requirement

A/A	16
Title	Instructional context characterization
Description	The platform will allow teachers to select the educational level, area of study, learning subjects, and learning resources that are important to worksheet preparation.
Roles	Teacher, Educational Expert
Prerequisites	• The user should be logged in

Status after completion	When creating a worksheet, the platform tags it with metadata for a variety of information categories such as learning subject, difficulty, grade level, and so on. This metadata aids in determining the worksheet's size and available material, as well as assisting the personalization process in providing the learner with the appropriate objects.
Main Success Scenario	• The user visits the worksheets skeletons page • The user selects to create worksheet skeleton action • The user enters the basic worksheet skeleton title and description, as well as some basic metadata like grade level and public visibility status. • In the second stage, the user characterizes the worksheet skeleton using structural tags such as the bloom level and targeted cognitive levels, which ultimately dictate the worksheet's size and the available learning objects for the skeleton. • The user selects all the required learning objects • Finally, preview the skeleton and submit the final design.
Exceptions	• In the event that the user does not fill out all of the required metadata fields, the system will display a warning message informing him to audit the information. • In the case that the user in the last step does not select the required amount of learning objects or does not select objects in all the required bloom dimensions, the system does not allow the user to progress in the next and displays a warning message in the form.

Table A. 17 Review of Proposed Learning Objects Requirement

A/A	17
Title	Review of Proposed Learning Objects

Description	The platform shall allow teachers to review and adjust the platform's proposed learning objects before final assignment to learners.
Roles	Teacher, Educational experts
Prerequisites	• The user should be logged in
Status after completion	The platform enables filtering of learning objects and simplifies the process of checking accessible learning things.
Main Success Scenario	• The user visits the learning objects page • The user filters the learning objects according to the curriculum and the worksheet skeleton design • The user evaluates the available learning objects • The user decides if the platform already offers enough relevant objects and whether he proceeds to learn object creation
Exceptions	-

Adaptive Recommendation and Worksheet Generation

Table A. 18 Personalized Worksheet Generation Requirement

A/A	18
Title	Personalized Worksheet Generation

Description	The platform will create personalized worksheets for each learner based on their profile, preferences, and pedagogical requirements.
Roles	Student, Teacher
Prerequisites	• The user should be logged in • The student should already have initialized their learning profile for the specific learning style.
Status after completion	The platform should take into account the student's learning profile and generate a worksheet that is not always the same but is tailored to the student's specific needs.
Main Success Scenario	• The student visits the worksheet skeleton page • The platform fetches the learning profile and runs the recommendation algorithm to evaluate the learning objects • The platform generates the personalized worksheet • The platform redirects the user in the list of personalized generated worksheets
Exceptions	• In case of a student that does not have an initialized profile for the worksheet skeleton learning style, the platform will redirect the learner to the learning style questionnaire.

Table A. 19 Use of Learning Style on Recommendation Requirement

A/A	19
Title	Use of Learning Style on Recommendation

Description	The platform shall use learning-style information as part of the recommendation and worksheet assembly process.
Roles	Student
Prerequisites	-
Status after completion	Each worksheet skeleton is associated with a learning style and is part of the recommendation system, which makes recommendations depending on the learner's performance in that specific learning style.
Main Success Scenario	-
Exceptions	-

Table A. 20 Hybrid Recommendation Logic Requirement

A/A	20
Title	Hybrid Recommendation Logic
Description	To improve recommendation quality, the platform will combine content-based and collaborative recommendations based on similar students and learning objects during the scoring process. To improve recommendation quality, the platform will combine content-based and collaborative recommendations based on similar students and learning objects during the scoring process.

Roles	Student
Prerequisites	-
Status after completion	The recommendation algorithm of the platform is a hybrid algorithm that considers the current performance of the student on the current course and learning style, also considers the similar users and learning objects which is also a dynamic feature that is not related directly with the user performance.
Main Success Scenario	-
Exceptions	-

Learner Interaction and Worksheet Execution

Table A. 21 Present All Active Worksheet Skeletons Requirement

A/A	21
Title	Present All Active Worksheet skeletons
Description	The platform shall present currently available worksheets skeletons to each student for selection and completion.
Roles	All
Prerequisites	• The user should be logged in • The learner must have completed the learning style questionnaire and initialized learning style profile for the worksheet skeleton.

Status after completion	The platform allows users to go to the worksheet skeleton page and preview all of the skeletons and filter them, while also allowing students to generate any public worksheet from any skeleton.
Main Success Scenario	• The Student visits the worksheet skeletons page • The student filters the worksheet skeletons to find the available for target course • The student selects the suitable skeleton • The student generates the worksheet
Exceptions	• In case of a student that does not have an initialized profile for the worksheet skeleton learning style, the platform will redirect the learner to the learning style questionnaire.

Table A. 22 Worksheet completion by Student Requirement

A/A	22
Title	Worksheet completion by Student
Description	The platform shall allow students to read and complete assigned worksheets within the platform environment.
Roles	Student
Prerequisites	• The user should be logged in • The worksheet should not be completed

Status after completion	The platform allows the student to access the generated worksheets and submit all evaluation objects answers to complete worksheets.
Main Success Scenario	• The Students visits the worksheets page • The Student selects a non completed worksheet • Reads the learning objects and answers the evaluates objects • Completes the worksheet and submits the responses to make the worksheet available for grading
Exceptions	-

Table A. 23 Edit Worksheet Response fields Requirement

A/A	23
Title	Edit Worksheet Response fields
Description	The platform shall allow students to edit all response fields within worksheet activities where learner input is required before the final submission of the worksheet.
Roles	Student
Prerequisites	• The user should be logged in • The worksheet should not be completed
Status after completion	The student can edit all of the answers to the assessment objects as long as the entire worksheet is submitted.

Main Success Scenario	• The Students visits the worksheets page • The Student selects a non completed worksheet • The student answers the first evaluation object and proceeds to the next one. • The student stops and saves the worksheet current status • The student after some time returns to the worksheet and goes back to the first step and updates the response of the evaluation object • The student completes the rest of the worksheet • The student submits the final version of the worksheet
Exceptions	-

Table A. 24 Support Blended Use Requirement

A/A	24
Title	Support Blended Use
Description	The platform shall support worksheet use in both classroom and out-of-classroom settings in accordance with the blended learning model.
Roles	Student, Teacher
Prerequisites	• The user should be logged in • The selected worksheet should not be completed

Status after completion	The platform enables for asynchronous submission of answers to the evaluation object, as well as empty answer submission or transfer the classroom work in digital form if some of the answers were completed physically in the classroom.
Main Success Scenario	• The Teacher demands to work an answer of an evaluation object in classroom • The student access the worksheet from home or for a digital device in classroom • The student either leaves the answer empty or with a comment or transfers the physical answer developed in classroom in a digital form • The student submits the completed worksheet
Exceptions	-

Table A. 25 Feedback on Enjoyment and Experience Requirement

A/A	25
Title	Feedback on Enjoyment and Experience
Description	The platform shall allow students to provide feedback on worksheet enjoyment and overall learning experience.
Roles	Student
Prerequisites	• The user should be logged in • The worksheet should not be completed

Status after completion	The platform asks the student between each assessment object execution to evaluate their preference, and at the end of a worksheet to assess overall student satisfaction.
Main Success Scenario	• The student access a on going worksheet • The student answers the evaluation object • The platform begins by asking the learner to rate the evaluation object on a scale of 1 to 5. • The student continues the worksheet and evaluates between each answer • At the end of the worksheet to evaluate the whole worksheet satisfaction on a scale of 1 to 5.
Exceptions	-

Assessment, Monitoring, and Adaptive Feedback Loop

Table A. 26 Teacher Evaluate learners work Requirement

A/A	26
Title	Teacher Evaluate learners work
Description	The platform shall make learner progress and performance data available to teachers for instructional monitoring and intervention.
Roles	Teacher
Prerequisites	• The user should be logged in • The worksheet skeleton should be created or copied by the Teacher

Status after completion	The Teacher can view and evaluate all the recommendations of the generated worksheet and understand the learners educational progress and profile.
Main Success Scenario	• The teacher visits the worksheet skeletons page • The teacher filter his personal worksheet skeletons • The teacher selects each skeleton that is part of the course • The teacher evaluates the generated worksheets for each student that monitors • The teacher checks the recommended objects • The teacher proceeds to design the next worksheet skeleton
Exceptions	-

Table A. 27 Use of Evaluation Outcomes for future adaptations Requirement

A/A	27
Title	Use of Evaluation Outcomes for future adaptations
Description	The platform shall use evaluation outcomes to update future personalisation and recommendation decisions.
Roles	Students
Prerequisites	-

Status after completion	The platform generates scores based on the worksheet performance scores of students in each course and learning style, while also using the stored scores of students and learning objects to find similar learning objects scores and similar students and use them as parameters to learning object scoring.
Main Success Scenario	-
Exceptions	-

A.2 Non-Functional Requirements

Pedagogical Quality and Personalization

Table A. 28 High Degree of Personalization Requirement

A/A	28
Title	High Degree of Personalization
Description	The platform shall provide a high degree of personalization by adapting educational content to learner profiles, preferences, performance patterns, and learning-style information.
Roles	Teacher, Student, Educational Expert, Content Creator
Prerequisites	-

Status after completion	The platform provides large scale tagging in all the pedagogical element and utilize them as tool for the creating a detailed scoring for each individual student learning profile and utilize them as critical parameters to the recommendation logic
Main Success Scenario	-
Exceptions	-

Table A. 29 Support for the Development of the 4Cs Requirement

A/A	29
Title	Support for the Development of the 4Cs
Description	The platform shall support the long-term educational goal of fostering the 4Cs through structured and adaptive learning pathways.
Roles	Teacher, Student, Educational Expert, Content Creator
Prerequisites	-
Status after completion	The platform has at its core design to target cognitive skills and for that reason 4Cs is a core element. In many aspects 4Cs exist as metadata tagging that affects directly the selection of learning objects and the recommendation logic.
Main Success Scenario	-

Exceptions	-

Usability and User Experience

Table A. 30 Teacher Interface Usability Requirement

A/A	30
Title	Teacher Interface Usability
Description	The platform shall provide a simple and clear interface for teachers during classroom setup, worksheet preparation, and review evaluation objects.
Roles	Teacher
Prerequisites	-
Status after completion	The platform provides the Teacher with a simple and intuitive UI to read all of the available educational information (learning methods, learning subjects, etc.) and aims to have simple preview pages for worksheet skeletons, learning objects, etc. with intuitive filtering, while also attempting to display clearly the completed worksheets with all of the required information to make the evaluation process easier. Finally, on the worksheet skeleton creation it includes a stepper form that divides the tagging and learning object selection process of the worksheet skeleton and concludes with a full view of the skeleton preview to allow the teacher to identify any unintended mistakes.
Main Success Scenario	-
Exceptions	-

Table A. 31 Low Interaction Complexity Requirement

A/A	31
Title	Low Interaction Complexity
Description	The platform shall minimise unnecessary interaction complexity so that essential tasks can be completed without extensive technical support.
Roles	ALL
Prerequisites	-
Status after completion	The platform's UI design adheres to industry standards that are familiar to the user in order to make platform navigation natural, with the purpose of reducing the need for technical help and guidance.
Main Success Scenario	-
Exceptions	-

Reliability, Availability, and Resilience

Table A. 32 Timely Worksheet Generation Requirement

A/A	32
Title	Timely Worksheet Generation

Description	The platform shall generate personalised worksheets within response times suitable for authentic educational use.
Roles	Student
Prerequisites	-
Status after completion	The platform has split the services with the appropriate context separation using the microservices design, and by leveraging RestAPI, a lightweight protocol for communication between services, the platform has successfully reduced network overhead. Furthermore, the constant update of the student's profile allows for an updated image for the student's learning profile, allowing the score to be calculated through the recommendation algorithm and the worksheet to be generated in a very short period of time, making it perfect for a live online app.
Main Success Scenario	-
Exceptions	-

Table A. 33 Efficient Data Retrieval Requirement

A/A	33
Title	Efficient Data Retrieval

Description	The platform shall use lightweight communication mechanisms between internal components in order to reduce latency during adaptive operations and must support the quick retrieval of learner and content data required for adaptive recommendation, worksheet building, and general display of accessible information with very short data retrieval times and no need for repetitive requests.
Roles	ALL
Prerequisites	-
Status after completion	Using Rest API, a lightweight protocol for communication between services, allows the platform to have very minimal network overhead, and by using proper approaches in the frontend, the platform eliminates multiple requests, resulting in a very quick and lag-free user experience.
Main Success Scenario	-
Exceptions	-

Table A. 34 Efficient Processing of Educational Data Requirement

A/A	34
Title	Efficient Processing of Educational Data
Description	The platform shall maintain acceptable performance while processing structured and semi-structured educational data.

Roles	ALL
Prerequisites	-
Status after completion	Due to the nature of the hybrid algorithm, the service has a modest network overhead, and the method executes with great performance in a short amount of time.
Main Success Scenario	-
Exceptions	-

Scalability, Extensibility, and Interoperability

Table A. 35 Reliability of Core Functions Requirement

A/A	35
Title	Reliability of Core Functions
Description	The platform shall provide reliable behaviour during worksheet creation, recommendation, execution, and evaluation.
Roles	ALL
Prerequisites	-

Status after completion	The platform employs a dependable algorithm based on a hybrid algorithm implementation that produces a consistent outcome in which if the data remains unchanged.
Main Success Scenario	-
Exceptions	-

Table A. 36 Reduction of Failure Propagation Requirement

A/A	36
Title	Reduction of Failure Propagation
Description	The platform shall reduce the risk that failure in one functional area compromises the operation of the whole system.
Roles	-
Prerequisites	-
Status after completion	The platform is developed using the microservices architecture, which allows the system to be separated into multiple services, each of which implements a separate context. This implementation reduces the failure of the whole platform in case one of the services fails at the same point.
Main Success Scenario	

Exceptions	-

Table A. 37 Resilience Under Changing Workload Requirement

A/A	37
Title	Resilience Under Changing Workload
Description	The platform must be able to operate reliably even under shifting workload conditions and routine educational usage.
Roles	-
Prerequisites	-
Status after completion	The platform is built on the microservices architecture, which allows the system to be divided into several services, each of which implements a distinct context. Furthermore, the microservice can be accessible through a central authentication gateway, which serves as a proxy for the rest of the platform. This architecture is built for large workloads and provides for easier horizontal scaling if the system has to be more resilient in the face of heavy workloads.
Main Success Scenario	-
Exceptions	-

Table A. 38 Service Continuity During Evolution Requirement

A/A	38
Title	Service Continuity During Evolution
Description	The platform must ensure service continuity throughout modular upgrades and steady system evolution, if possible.
Roles	-
Prerequisites	-
Status after completion	The platform is developed on the microservices architecture, which allows the system to be divided into several services, each of which implements a distinct context. This implementation lowers the need for updates and repairs while the system is still running, avoiding conflicts with the rest of the platform's functions.
Main Success Scenario	
Exceptions	-

Maintainability, Modularity, and Testability

Table A. 39 Extensibility of adaptive frameworks Requirement

A/A	39
Title	Extensibility of adaptive frameworks

Description	The platform must be adaptable to facilitate the integration of additional services, suggestion signals, learning-style models, and pedagogical resources without necessitating significant redesign.
Roles	-
Prerequisites	-
Status after completion	The platform is developed on a microservices architecture that divides the system into multiple services, each with its own context, implementations, and isolated databases. This enables each service to be designed using different technologies or databases that better meet the individual service requirements.
Main Success Scenario	
Exceptions	-

Table A. 40 Openness to future Integration Requirement

A/A	40
Title	Openness to future Integration
Description	The platform will be available for future integration of new educational tools, repositories, and recommendation algorithms.
Roles	-

Prerequisites	-
Status after completion	All of the services were created with a clean architecture and flexibility in mind for the database schema design, allowing for the inclusion of more tools, external learning objects, and learning styles, among other things.
Main Success Scenario	-
Exceptions	-

Security, Privacy, and Data Protection

Table A. 41 Secure Data Storage and Prevention of Unauthorized Access Requirement

A/A	41
Title	Secure Data Storage and Prevention of Unauthorized Access
Description	The platform must securely save learner information, worksheets, and evaluation data, with authorization data encrypted, and the system must prohibit unauthorized third-party access to stored educational data.
Roles	-
Prerequisites	-
Status after completion	The platform saves the authorization data encrypted and securely saves data in databases that cannot be viewed externally, and are not exposed to third-party services.

Main Success Scenario	-
Exceptions	-

Data Integrity and Consistency

Table A. 42 Integrity of Educational Data Requirement

A/A	42
Title	Integrity of Educational Data
Description	The platform shall preserve the integrity of learner, worksheet, and content data across all functional areas.
Roles	-
Prerequisites	-
Status after completion	All of the services' data schemas are designed to be independent of one another, and all of the data required to maintain history and update the learners' profiles is carefully stored.
Main Success Scenario	-
Exceptions	-

Table A. 43 Consistency Across Components Requirement

A/A	43
Title	Consistency Across Components
Description	The platform shall manage coordination among its internal components in a way that minimizes data inconsistency.
Roles	-
Prerequisites	-
Status after completion	All systems are designed to follow a clean architecture and feature consistency architecture to aid development and eliminate inconsistencies with database schema design.
Main Success Scenario	-
Exceptions	-

Deployability and Operational Support

Table A. 44 Support for Modular Deployment and Automated Build Requirement

A/A	44
Title	Support for Modular Deployment and Automated Build

Description	The platform shall support modular deployment of its major components across technical environments and shall support automated build, test, and deployment processes in order to improve operational consistency.
Roles	-
Prerequisites	-
Status after completion	The platform deployment is intended to operate with containerized builds using Docker, allowing the builds to function normally without being influenced by the technological environment. This system is also integrated with the Jenkins orchestration tool, enabling automated, consistent, and testable builds and deployments.
Main Success Scenario	• The developer pushes an updated version to git • The Jenkins trigger the build of the specific services and triggers the redeployment • The new service is live after the successful build
Exceptions	-

Table A. 45 Versioning and Operational Manageability Requirement

A/A	45
Title	Versioning and Operational Manageability

Description	The platform shall support reliable versioning and operational management of independently evolving components.
Roles	-
Prerequisites	-
Status after completion	Each version created by a developer is pushed to the git environment, and each game update generates a new version.
Main Success Scenario	-
Exceptions	-