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Designing Learning Paths with Open Educational Resources: An Investigation in Model-Driven Engineering

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***Abstract*—This paper presents a methodology for supporting educators and learners in designing and delivering learning paths using Open Educational Resources (OERs). While OERs provide free and unlimited access to high-quality learning resources, their scattered nature presents significant challenges in finding relevant and high-quality materials. Furthermore, the lack of a centralized repository for OERs makes it difficult to ensure the accuracy and quality of the materials being queried. To address these issues, the paper presents the ENCORE methodology that provides software components, or ENCORE enablers, to enable educators to include relevant OERs that target specific skills in their learning paths. The methodology also leverages notebook interfaces and gamification mechanisms to promote stu- dents' learning engagement. The paper illustrates the ENCORE methodology through a case study, where the methodology is applied to an OER repository of educational resources developed by the expert network on model-driven engineering (MDEnet). The case study demonstrates that designing the database and enablers as independent but holistic components enables the use of OERs to accomplish a wider range of educational goals, such as supporting the creation of learning paths. The paper concludes with indications on how to extend the ENCORE methodology to further enhance the creation and delivery of personalized learning experiences, supporting the reuse of open educational resources and the automatic generation of personalized learning paths.**

***Index Terms*—open educational resource, web scraping, model- driven engineering, learning paths**

I. Introduction

Open Educational Resources (OERs) [1] are educational materials freely available for use, reuse, and redistribution. OERs are created and shared by educators and organizations to provide access to high-quality educational materials to as many people as possible. OERs encompass indeed a diverse range of topics and formats, including textbooks, lesson plans, educational videos, slides, exercises, audio recordings, and more.

The widespread availability of OERs has challenged educators to navigate a vast array of resources to create meaningful interventions that address the constantly evolving needs of learners. This challenge has led to a redefinition of the role of educators, who must now work to design effective educational strategies that incorporate OERs while addressing learners' ever-changing skill needs. Intelligent systems can enhance educators' role in several ways, including offering recommendations for educational content, providing personalized learning experiences, and automating laborious tasks. By assuming certain responsibilities, these technologies can help educators focus on creating more engaging and interactive learning experiences for their students. However, it is crucial that educators receive adequate training and resources to effectively utilize these systems to enhance their pedagogy and teaching practices. This includes understanding how to integrate them seamlessly into their teaching and learning activities and how to interpret and use the data generated by these systems.

The project ENCORE [2] aims to support this shift by developing an intelligent system that suggests quality OERs to support the pedagogical design and teaching around key skills affected by societal macro-trends, i.e., Green, Digital, and Entrepreneurial (GDE) skills. The project has two phases: a data-driven phase using Natural Language Processing to match skills with relevant OERs and a qualitative/expert-driven phase for developing pedagogical guidelines and testing the system in real educational contexts.

Learning does not only happen in the classroom or formal settings. It can take place at home, at work, or even on the go. Learning activities can (and should be) tailored around the individual. This *personalization* process is critical when targeting neurodiverse profiles or students with accessibility needs. This personalization involves tailoring the content's form and delivery and providing additional aids to make the learning experience impactful. From a student's perspective, effective teaching means *1-1 tutoring* [3]-[5]. This allows teachers to provide feedback and explanations relevant to the student's experiences. On the other end of the spectrum, the most teacher-effective approach is the one-to-many lecture, where the teacher prepares the material upfront for being presented to a wide audience. However, this approach encourages also passive learning, which is one of its main downsides. A study by Koedinger et al. shows that the "Doer Effect" is a causal association between practice and learning outcomes and that practicing is six times more effective than reading [6]. Another significant drawback lies in the motivational aspect. *Active learning* is more effective in learning outcomes and motivation than passive learning [7]. Despite that, there are studies that highlight a negative correlation between students' actual learning and their perception of learning [8]. However, gamification and serious games gained consensus as tools to motivate people to engage in beneficial activities, even if seen as unrewarding or tedious [9]–[12].

When designing a learning experience, it is essential to consider all these relevant factors. However, it is equally important not to make any assumptions about the type of content, its form, delivery, and validation. A design framework should focus on removing obstacles between the teacher, the student, the environment, and the learning experience, without imposing any preconceived notions on these aspects. Individual coaching is rarely feasible due to poor scalability, whilst one-to-many general training is scalable but lacks individualization altogether. This creates a gap that the approach proposed in this paper aims to fill. The proposed method supports both teachers and students by combining the benefits of individualized delivery and manageability using software personalization. Specifically, the proposed method relies on an OER extraction process that enables the centralization, characterization, and interoperability of OERs among different educational platforms.

The rest of the paper is structured as follows. Section II details the methodology followed to extract and centralize OERs and to design learning paths. Section III describes a case study of our approach in the context of model-driven engineering. Finally, Section IV discusses the outcomes of the case study, and Section V summarizes the conclusions reached through this work.

II. Materials and Methods

A. From ROER to OER: Retrieval workflow

Open Educational Resources are a valuable tool in modern education, giving students and educators free and unlimited access to high-quality learning resources. Yet, the scattered nature of OERs can cause substantial issues for both educators and learners.

Finding relevant and high-quality materials may be time-consuming and intimidating, with millions of resources dispersed across multiple repositories (ROERs) and platforms. Furthermore, the lack of a centralized repository for OER makes it difficult to ensure the accuracy and quality of the materials being queried.

This can cause confusion and dissatisfaction for educators and learners, and it can influence the overall success of OERs. As a result, it is crucial to address the issue of scattered OERs and strive toward developing a more streamlined and efficient system.

In this sense, one of the potential solutions is to centralize and unify the OERs scattered among several sources. The ENCORE project aims, among other goals, at building a common and enriched database with quality OERs linked to Green, Digital, and Entrepreneurial (GDE) skills.

Following this idea, a retrieval workflow has been designed and carried out to collect OERs from popular repositories, clean and unify their attributes, and assess their quality by analyzing their meta-data (Figure 1).

The approach considered is based on web scraping, to extract all the available meta-data from the OERs stored in different ROERs. The following activities are contemplated in the retrieval workflow:

1) Analyze the ROER website. The structure and features of popular OER repositories will be analyzed to understand the organization of their contents.
2) Develop scripts to extract OERs from ROERs. A script using the available functionality is developed if the ROER has an API. If the ROER does not have an API, a custom script for scraping the ROER's contents is developed.
3) Meta-data extraction. Extract the meta-data from each identified OER.
4) Quality filter. Apply the quality filter designed in previous tasks of the ENCORE project (out of the scope of this paper) to the extracted meta-data to retain quality and unique OERs. Records discarded during this activity are reported along with their justification.
5) Text extraction. Textual elements of the OERs will be extracted only if they comply with the quality filter (and if available).
6) Search for GDE skills. The selected OERs will be linked to GDE skills by using natural language processing (NLP) techniques to extract GDE concepts from the title and description of each OER (this activity is out of the scope of this paper, and it will be covered in subsequent research).
7) Store selected OERs. The selected OERs and their associated GDE skills will be persistently stored in the ENCORE database.

By using this framework and the Dublin Core Metadata Element Set (DCMES) [13], [14] to abstract the required metadata from OERs (title, description, format, publication date, creators, etc.), it is possible to tackle the centralization and unification of OERs from scattered sources.

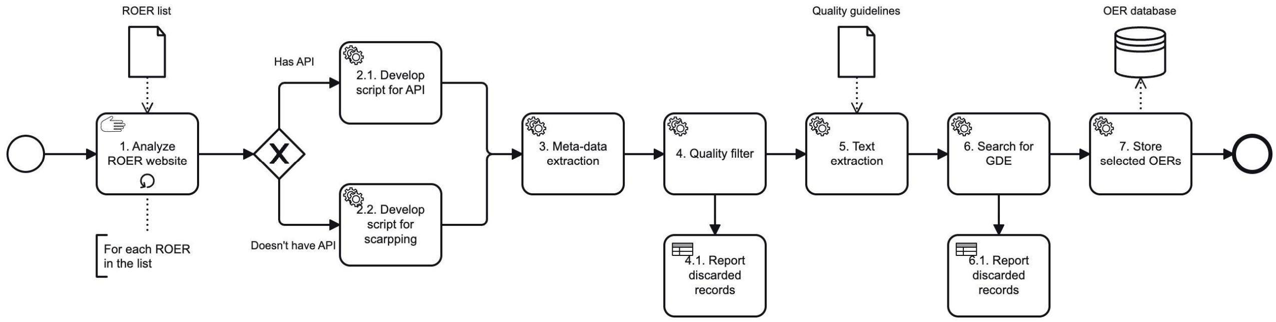

Fig. 1. BPMN diagram of the OER retrieval workflow.

In this context, the ENCORE database [15] is designed as an enriched ROER but also as a component of a technological ecosystem [16], [17] to create an interconnected network of technology platforms and tools that enable the creation, sharing, and dissemination of OERs.

B. Creating Learning Paths

A learning path is a sequence of learning activities that are designed to help students achieve specific learning outcomes [18]. In an academic setting, a learning path typically consists of a series of lessons or units that build on one another to create a cohesive educational experience. The process for creating a learning path generally involves two main steps: i) creating the learning path by identifying the learning objectives, selecting relevant content and assessment, and using the most appropriate instructional strategies, e.g., lectures, discussions, group activities, or assignments; and ii) delivering the learning path to students while monitoring students' progress and providing support when needed.

Creating a learning path can be challenging for educators and learners. Educators might find difficulties in selecting appropriate content that is aligned with the learning objectives while ensuring that content and assessments are delivered in a way that is engaging and effective for students. Considering the learners, while accessing the learning path, they need to be motivated to engage with the content and complete the assessments and might require accessing the learning path at their own pace and level of understanding.

The ENCORE methodology supports educators and learners in designing and delivering the learning path by providing software components, the ENCORE enablers. Using the ENCORE Enabler for Educators (E4E), educators can access the ENCORE database and include relevant Open Educational Resources (OERs) in the learning path that target specific skills. A second enabler, the ENCORE Enabler for Learners (E4L), supports the delivery of the resulting learning path to students by leveraging notebook interfaces. Each notebook can be configured to provide and assess a specific learning path and can be augmented with gamification mechanisms to promote students' learning engagement.

C. Learning Paths Authoring and Delivery

ENCORE provides an open, content-agnostic, and extensible framework (see Figure 2 for its architecture) for authoring and delivering adaptive and gamified learning experiences to deliver learning experiences entirely tailored to learners' needs and choices. For example, students should be able to do some lessons and quizzes while conversating with a voice-controlled interface (e.g., Alexa), switch to VS Code to complete some coding assignments, and then move to another front-end (e.g., Moodle) to get access other educational resources, all without friction. That is why we exploit the flexibility of .NET Interactive [19] as the enabler for learners (E4L). Learners interact with external tools through Adapters that bind actions on the learner front-end to .NET Interactive commands and bind .NET Interactive events to a supported output (e.g., audio for Alexa) with custom formatters.

The term "adaptive" in adaptive learning paths refers to the ability to adjust to learners' needs [20], [21]. This includes assigning exercises based on their previous responses and the capabilities of the platform they are using. This adaptation is made possible through collaboration between the Execution Engine and the Backend. The former handles the learners' submissions and validates their responses, while the latter uses the results of the validation phase to assign the next activity in the learning path. The two most important aspects of the ENCORE Enablers are the content creation process's simplicity and *availability* to learners to consume and educators for reuse. By prioritizing these aspects, the ENCORE Enablers can support adaptive learning paths that are effective and accessible for both learners and educators.

Creating and implementing effective learning paths for such a diverse and varied learning experience can present a considerable challenge. That is why the enabler for the educators (E4E) includes a Learning Path Editor [22] heavily focused on the educators' experience (see Figure 3).

Its graph-like, visual-editing capabilities and integration with the rest of the platform allow the creation of ready-to-use learning material easily, thanks to the abstractions provided. The E4E is composed of two main elements: the *drawing area* and the *properties panel*. The drawing area is the core of the visual editing experience. Nodes can be added, connected, and rearranged with simple clicks or drag-and-drop interactions. Nodes and edges can be interactive components augmenting the visual editing experience. The properties panel, instead, provides fine-tuning tools to define the activities and the links between them.

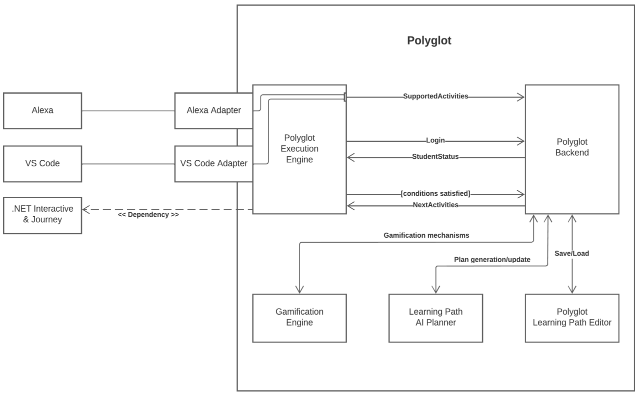

Fig. 2. E4E architectural overview.

To establish the learning path, the educator can undertake several steps. Firstly, they can generate new activities by accessing the context menu with a right-click on the canvas. Secondly, the educator can adjust the type and parameters of the activities from the properties panel. Finally, the educator can interconnect the activities by dragging from the source node's handle to the destination node's handle. Furthermore, the educator can modify the link condition by selecting the edge between two nodes and accessing the relevant options. This includes choosing from a pre-existing list of abstractions or creating their own validation criteria.

The adaptation process necessary for effective enablers relies on *abstract learning activities*: activities defined only in terms of their goals (i.e., learning objectives) and not on concrete exercises the students have to solve. Those abstract activities are then replaced during the runtime execution phase with the most suitable composition of existing learning activities that satisfy the goal the AI planner decides. The latter exploits the automatic generation of learning paths by adapting an existing approach based on AI planning [23]. The chosen learning activities may have other abstract activities, so further refinement stages may be needed.

Gamification refers to the use of game elements and mechanics in the design of an educational experience. This involves creating a game narrative that guides learners through increasingly complex challenges and engages them with social activities such as group work or competitions. It also entails providing immediate feedback and empowering students to make autonomous choices to progress down a path they have individually decided on. It is important to note that gamification is not just an add-on to the learning experience. Instead, gamification mechanics (supported by the Gamification Engine component of Figure 2) are fundamental to the process of personalizing the learning path. Not only do they keep the students engaged, but they also provide valuable insights into the student's behavior. This, in turn, can help generate a more personalized and engaging learning path tailored to each student's needs and preferences.

III. USE CASE: MDENET

MDENet [24] is the expert network on model-driven engineering (MDE). Funded by the UK Engineering and Physical Sciences Research Council (EPSRC) since 2021, it aims to drive future research by encouraging interaction and new collaborations, creating training materials and events, and communicating the benefits of MDE through success stories and events like a two-day annual symposium.

In developing training, MDENet has been developing learning resources and running regular online training sessions. For the learning resources, initially, MDENet concentrated on curating existing materials around specific topic areas in MDE. There already exist lots of material on MDE, but it is of differing quality and widely distributed, making it difficult for newcomers to the field to judge where to start and what materials to focus on. MDENet learning resources offer an opportunity to identify and present good material in a structure that contextualizes and relates topics meaningfully. Learning resources are freely available through the MDENet community platform [24].

This section provides an illustrative example of using MDENet resources to validate the OER extraction process's feasibility and integration with the ENCORE enablers.

A. Illustrative examples: A Learning Path for Basics in Epsilon Languages

Epsilon [25] is a family of Java-based scripting languages for automating common model-based software engineering tasks, such as code generation, model-to-model transformation, and model validation. The goal of this example is to show how using the methodology introduced in Section II, we can extract a set of OERs related to the Epsilon learning material available for the MDENet community and provide educators a way to generate learning paths for their students.

First, all the educational resources from MDENet were retrieved through the workflow described in Figure 1. In this case, because MDENet does not provide an API, a scraping script was designed to scrape the OERs contained in the "Learning Resources" section of the MDENet community. Each resource is classified by covering its topic, ranging from an overview of MDE to more specific resources about modeling languages (such as Xtext and Epsilon) or frameworks (such as the Eclipse Modelling Framework). This information, along with other meta-data (title of the OER, description, author, source, format, etc.), was scraped and stored in the ENCORE database to enrich the existing contents with MDE-related resources. A total of 73 resources from MDENet were stored in the ENCORE database.

The process of scraping all available meta-data from Open Educational Resources (OERs) can lead to a more thorough understanding of each resource. This can facilitate queries that help to retrieve relevant OERs based on specific educational goals.

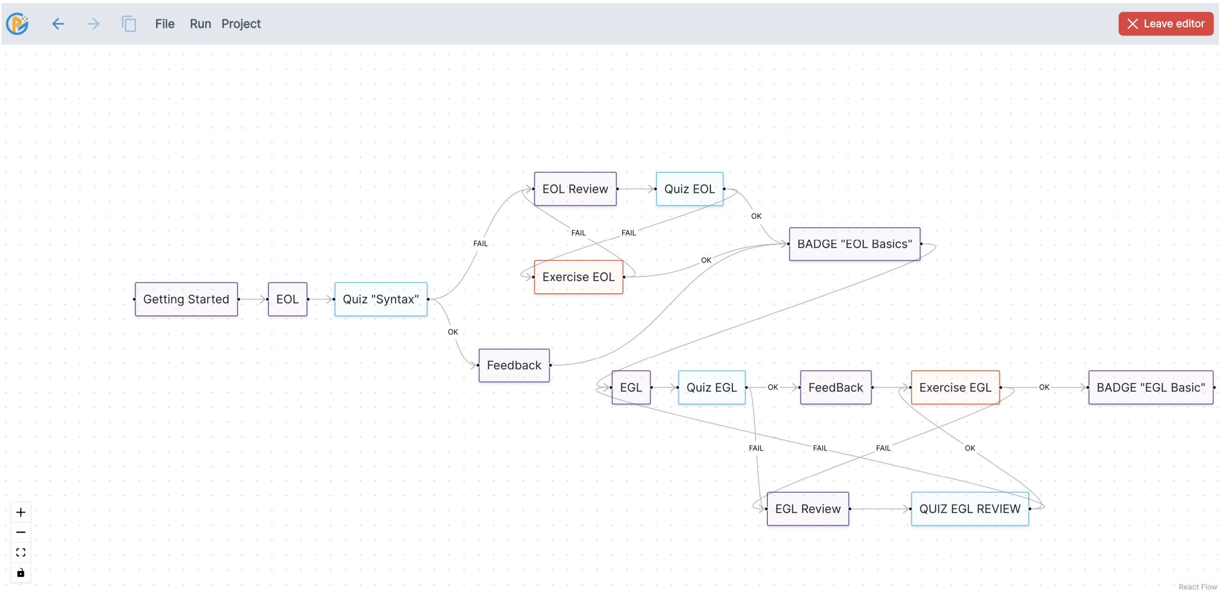

Fig. 3. Educator design tool for learning paths - E4E (Epsilon Learning Path).

In the context of this use case, which involves designing a learning path to teaching the foundations of the Epsilon language, the educator would need to retrieve introductory resources on this topic. To facilitate this process, the ENCORE database offers filtering features that allow users to search for relevant OERs using fine-grained attributes. These features can greatly assist in narrowing down the search and finding the most appropriate resources for the specific educational goal.

In this case, a filter was applied to the subject to offer introductory OERs related to the Epsilon languages using the following query strings: "Epsilon" and "MDE". This query returns a total of 17 OERs related to the Epsilon framework. The educator can perform additional queries to refine the results and extract resources on specific areas of the Epsilon framework, like the Epsilon Object Language, Epsilon Generation Language, Epsilon Transformation Language, etc.

After the relevant set of OERs has been extracted and presented to the educator, the proposed educational material can be used to develop a learning path for their students. In this specific example, the educator wants students to first learn about the Epsilon Object Language (EOL) since it is the core expression language of Epsilon. Once the students have completed the EOL learning objective, they move to learn the basics of the second language, the Epsilon Generation Language (EGL), to understand how it can be used to transform models into various types of textual artifacts, including code (e.g., Java), reports (e.g., in HTML/LaTeX), images (e.g., using Graphviz), formal specifications, or even entire applications comprising code in multiple languages (e.g., HTML, JavaScript, and CSS).

The educator has identified three types of specific learning activities required to define the scenario: lessons, quizzes, and modeling exercises (as depicted in Figure 3). If a student fails a quiz or a modeling exercise, the learning path provides a Review Lecture and an additional Quiz to reinforce their understanding before proceeding. Once students have completed the first section on the EOL, they move to the second part, where they can learn the remaining language (i.e., EGL) following the same pattern as the first section. Gamification has the role of motivating the students while executing the learning activities. This is done thanks to a set of game elements (i.e., badges) that link the successful execution of learning activities to the advancement in the game narrative (i.e., BADGE nodes in Figure 3).

The student can consume learning paths thanks to the Execution Engine component of Figure 2 through standard Visual Studio Code notebooks (see Figure 4 and Figure 5).

IV. Discussion

The main contribution of this paper can be summarized in Figure 6 and detailed in this section.

Regarding the OER extraction method, the retrieval approach proposed in Section II has proved to be successful in different contexts, including generic ROERs, such as OERCommons [26] or Merlot [27], and domain-specific ROERs, like MDENet.

Finally, the ENCORE database and enablers have been designed as components of a technological ecosystem, enabling information flows among different platforms to enrich and foster the accessibility of OERs.

One of the primary benefits of a technological ecosystem approach is that it allows educators to share and reuse existing materials, which can assist in overcoming the scarcity of OERs. For example, if a teacher wishes to build a new learning scenario (i.e., Course, Lesson, Seminar, Workshop, etc..) on a specific set of Skills, they can take current OERs as a starting point and adapt them to match their needs. This method saves time and ensures that the produced resource is suited to the unique needs of the instructor and their pupils.

Furthermore, a technological ecosystem strategy can help to secure the long-term viability of OERs by offering a platform for continued cooperation and support, leveraging the flexibility and scalability that this approach provides.

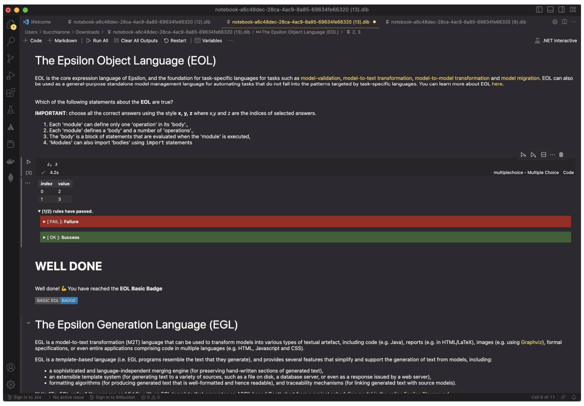

Fig. 4. EOL part of the learning path.

Fig. 5. EGL part of the learning path.

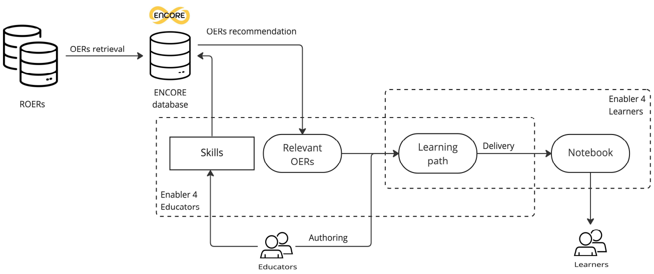

Fig. 6. The ENCORE ecosystem.

This use case has illustrated that by designing the database and enablers as independent yet interconnected components, it becomes possible to utilize OERs for a broader range of educational objectives. In this specific instance, such an approach has facilitated the creation of learning paths.

Regarding the *authoring* and *delivery* of Learning Paths, the two enablers (namely, E4E and E4L) in their current state of development offer an interactive, engaging, and motivating learning experience for students. Their flexibility allows educators to seamlessly incorporate diverse activities, such as reading, quizzes, and modeling exercises, into comprehensive learning paths that can be tailored to individual students. Furthermore, these enablers support students in revising complex concepts as they work towards achieving their learning objectives. Given the expandability of these enablers, they serve as an excellent foundation for creating additional content (i.e., learning paths). As such, the proposed solution enables students to engage in non-conventional learning experiences while also leveraging the benefits of an active and constructive learning approach.

V. Conclusions

This work presents an approach to centralize and unify OERs into the ENCORE database, a ROER, intending to foster the accessibility and reachability of these resources. The retrieval approach has been validated by extracting relevant and quality OERs from more than 10 general ROERs.

The ENCORE database is complemented with an API that enables interoperability among different systems, which can employ educational resources for different educational goals.

In this case, the ENCORE database and a Learning Path Editor have been tested to validate the suitability of its resources and features in a real-world example. On the other hand, this use case has also validated the feasibility and scalability of the approach by scraping OERs from new repositories (MDENet, in this case). Future research will involve user testing, as it is crucial to validate the usability of the presented tools to provide educators and learners with helpful resources and learning paths.

In this direction, we have presented the initial concepts for the learning enabler, designed for both educators and learners. We provided an overview of its architecture and demonstrated how the different learning phases are interconnected. This practical example helps to illustrate how the framework handles the overall ENCORE learning process.

The *adaptation process* relies on *abstract activities* which are defined in terms of their goals, such as concepts to learn or skills to obtain, without referring to concrete exercises that students must solve. These abstract activities are then replaced with the most suitable composition of existing learning fragments that meet the goal of an AI planner. The AI planner leverages the automatic generation of learning paths by adapting an existing approach based on AI planning presented in [23].

To make this extension possible, we need the availability of a substantial amount of learning fragments to choose from. We think that creating an *open learning fragments database* would benefit learners (with better refinement and high-quality educational content) and educators who can focus on the big picture and let the platform adjust the details.

Finally, we plan to add *support for existing learning management systems* [28] (e.g., Moodle LMS) in a modular fashion, like how we implement learners' front ends. This extension would enable a step-by-step integration of our solution with existing learning infrastructures and potentially increase the adoption of adaptive learning technologies and open educational contents.

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