Abstract: Current research on personalized learning environments has a strong focus on the individualized sequencing of learning objects and the creation of adaptive feedback within them. Little emphasis has been placed on designing virtual learning environments (VLEs) that retrieve the necessary learning objects from online repositories and utilize semantic metadata to present them dynamically. Thus, this paper presents an approach for transforming a semantic web of fine-grained learning objects into a functional VLE that delivers these objects to learners.

Keywords: Learning Objects, Virtual Learning Environments, Personalized Learning, Linked Data, Semantic Web

1 Introduction

The potential to personalize instruction using digital technologies was recognized more than half a century ago [GNR02]. This pursuit might culminate in the utilization of machines that possess human-like abilities for educational purposes [La23]. Such systems are envisioned to "automatically find appropriate learning objects that support an individual learner at some diagnosed stage of learning" [Pa04]. To accomplish these tasks, machines must make meaning of the world [Us03] and understand the educational content they present and adapt. This meaning is often conveyed from human to machine through semantic information [Us03]. While the automatic educational decision-making processes operate behind the scenes, their outcomes, such as how learning content and adaptive feedback is presented to the learner, must manifest in the user interface of the personalized learning environment. To illustrate this aspect of personalization, we present preliminary results of adlete-vle – a prototypical virtual learning environment (VLE) that leverages semantic information for the presentation of fine-grained learning objects to the learner.
2 Related Works

The fundamental idea of learning objects (LOs) is to "make online instructional materials broadly accessible, searchable, and reusable" [Pa04]. Digital learning objects play a pivotal role in achieving the goals of computerized education by creating instruction that is "(1) adaptive to the individual, (2) generative rather than pre-composed, and (3) scalable to industrial production levels without proportional increases in cost" [GNR02]. Reusable LOs are thus an important facilitator for advanced forms of computerized education such as the use of intelligent machines to personalize learning [GNR02]. By adopting an "authoring-by-aggregation" approach [DH03], smaller LOs can be reused by composing them into larger LOs or assembling them into learning sequences [Ve08]. As such, the granularity of LOs – their "size" [YKS20] – can range from a snippet of text (e.g. a definition) to a whole course [Ve08]. In order to reuse existing LOs, they must first be discoverable and accessible [Pa04], e.g. via Learning Object Repositories [YKS20]. Metadata about LOs is crucial for enabling this discoverability [Pa04] as well as ensuring interoperability between LOs and infrastructure such as learning management systems (LMS). In order to embed and assemble LOs, the infrastructure has to process both the metadata of the LO as well as the content (e.g. file format, encoding, etc.) [DH03]. Multiple metadata standards exist to describe the attributes of LOs (e.g. LOM, Dublin Core, AMB [Ko22]), types of LOs and their granularity (e.g. SCORM), the sequencing of LOs as well as their packaging for LMS [Ve08]. AMB ("Allgemeines Metadatenprofil für Bildungsressourcen") is a cross-educational metadata profile for the description of LOs, which is heavily based on the online vocabulary schema.org and its educational extensions by the Learning Resource Metadata Initiative [Ko22]. The JSON-based metadata format combines various properties for general information (e.g. name, language), pedagogical information (e.g. learningResourceType), technical information (e.g. encoding) and links to other sources, e.g. the competencies taught, assessed, or required by the LO [Ko22]. The metadata document itself is an independent web resource [Ko22].

Research on the presentation of fine-grained learning objects in VLEs using semantic technologies is rare. Yoosooka & Wuwongse demonstrate an approach for dynamically creating personalized learning packages in the SCORM format based on linked data techniques. However, the student must manually import the package in a SCORM-compliant LMS (e.g. Moodle) [YW12]. Based on semantic annotations, Henning et. al. deliver open educational resources to learners by embedding them in an LMS [He14]. In contrast, Milutinović et al. created a mobile application that retrieves fine-grained LOs and their linked resources from an LO repository and presents them within custom interactive learning activities [Mi15]. However, none of these publications provide in-depth information about the presentation of LOs from a technological perspective.

3 Design & Development

Undoubtedly, the presentation of learning objects plays a crucial role in facilitating
meaningful learning experiences for learners. This publication puts a special focus on the presentation of fine-grained LOs, which may not be bigger than snippets of information. Our fundamental assumption is that future intelligent algorithms, accountable for generating personalized learning sequences and assembling composite LOs, will employ an authoring-by-aggregation approach, harnessing the potential of reusable, fine-grained LOs. From a technological perspective, the delivery of such aggregated LOs and their constituent components requires the retrieval and subsequent presentation of these snippets to the learner. Subsequently, we will describe how this presentation of LOs within a prototypical VLE is informed by the semantic information associated with the LOs. However, the discussion of personalization algorithms falls beyond the scope of this paper.

In order to decouple the core logic of the VLE from the contents presented, adlete-vle requires LOs to be semantic web resources possessing unique identifiers (URLs). They must additionally be accompanied by metadata in the form of AMB. The VLE is given a learning object sequence, which contains the links to the LO web resources that are to be presented to the learner. Leveraging this information, the VLE gathers the LOs and their metadata from the web. The LOs of the prototype’s exemplary domain reside in a self-hosted LO repository that is a combination of OERSI (a search engine for LOs that uses and serves AMB metadata [Ho23]) and a simple web server (for LO content data).

*Figure 1: Process logic within the VLE (LO retrieval in blue, presentation in green)*

adlete-vle provides an integrated course experience, where learners stay in the VLE and are not redirected to external resources. As such these external resources need to be visually embedded. A wide variety of digital LO types exist, from simple textual LOs (e.g. definitions, examples, and hints) to multi-media content (e.g. videos, interactive simulations). To optimize their instructional value, it is crucial to present them in a way that reflects their specific type. To this end, the frontend of the VLE was developed in the form of a web-based application built with the React framework, and uses the model-view-controller and factory design patterns [Wa02]. Consequently, the models (LO content, e.g. textual definitions, images) are displayed by views (React components, e.g. text blocks, image galleries), which are dynamically created using the factory design pattern (see Figure 1). The semantic information about the LOs stored in the metadata plays a crucial role in this process. Metadata fields like `learningResourceType` (e.g. `definition`, `example`, `assessment`) and `encoding` (media types, e.g. `text/markdown`) are used for automatically
selecting the appropriate view component factory for a specific LO. A set of reusable view components was created for common learning resource types, e.g. Definition, Example, Equation and Video. Besides the LO content that is displayed, some of these components make direct use of the associated semantic data. The Definition component, for example, uses the concept referenced in the about field, when displaying the title. The Example component adds an illustrative image by utilizing the thumbnail field.

adlete-vle also supports the display of interactive LOs, either in the form of embedded websites or custom view components. Unlike static LOs that primarily consist of raw data, the latter LOs are self-contained React components associated with the particular media type application/x.react-component. These components have access to the underlying system, thereby enabling the retrieval and nested display of other LOs. This may, for instance, be used for the adaptive display of scaffolded information (e.g. hints, or links to LOs containing prerequisite knowledge). In certain domains, for example math, this can also be used to dynamically load additional datasets from external sources, allowing the learner to explore the learning content in the light of different contexts (e.g. sports vs. music).

As fine-grained LOs, such as definitions and examples, are usually not displayed independently, the VLE currently presents the LOs in a sequential order as collapsible blocks with titles, similar to popular LMS, such as Moodle (as shown in Figure 2).

Figure 2: Screenshot of the VLE showing the block-based layout of multiple LOs

4 Discussion & Outlook

The current prototype of the VLE is limited in various aspects. While new view components can be added easily to the component library, the VLE currently only supports the rendering of the types of LOs that were necessary for learning in the exemplary domain
of the prototype. The rendering of LOs makes strong use of their metadata. In line with one of the main criticisms of LOs, we can confirm that creating the necessary metadata is a time-consuming process [Pa04], especially at this level of granularity. Prior research has explored areas such as automatic metadata generation and metadata editors [Ve08], which have the potential to support this process. In this regard, exploring the potential of AI technologies such as large language models (e.g., ChatGPT) for metadata generation appears as a promising avenue for future research.

A user study of the VLE revealed a generally positive attitude concerning the block-based presentation of LOs (see Figure 2), though a non-negligible number of learners felt that the user interface appears cluttered and the information seems disconnected because of this structure. One potential approach to address this issue could involve merging multiple smaller LOs by generating text bridges, aiming to create a more natural text flow while minimizing visual clutter. In this context as well, large language models emerge as a viable tool.

To deliver personalized learning experiences, the prototypical VLE will soon integrate with an adaptive learning engine that is currently under active research [Gn23]. While the semantic information linking LOs to their associated competencies is valuable for these intelligent adaptive algorithms, such competency relations can also be manifested in the user interface, e.g. as part of a learner-centric approach to learning analytics [Sp13]. For example, a learner-centric VLE could enable learners to directly navigate from the current LO to the subset of competencies influenced by that particular LO within an open learner model. This would empower learners with an understanding of how their learning experiences correspond to the system's decisions regarding their learning.

5 Conclusion

While the development of personalized learning environments presents various challenges in terms of automated educational decision-making (such as individualized learning sequences and adaptive feedback), this paper puts a special emphasis on the retrieval and presentation of learning objects within personalized learning environments. We introduced a prototypical VLE that extensively utilizes semantic information in the form of learning object metadata to embed external (composite) learning objects from the web. Moving forward, this VLE will serve as an experimental sandbox for investigating the diverse aspects of learning object presentation in personalized learning environments.

Bibliography


