Towards Designing and Evaluating an Adaptable Assistance System for Technology-Enhanced Vocational Education

Antje Proske[1], Hermann Körndle[1], Kristin Drexler[1], Julia Kirsten[1], Klara Schröder[1], Sebastian Kucharski[2(✉)], Tommy Kubica[2], and Iris Braun[2]

[1] Faculty of Psychology, Technische Universität Dresden, Dresden, Germany
{antje.proske,hermann.korndle,kristin.drexler,julia.kirsten,klara.schroder}@tu-dresden.de
[2] Faculty of Computer Science, Technische Universität Dresden, Dresden, Germany
{sebastian.kucharski,tommy.kubica,iris.braun}@tu-dresden.de

Abstract. Intelligent tutoring systems collect learners' traces in technology-enhanced learning environments with the aim of guiding and improving their learning in real time. Research has succeeded in developing data models that optimize the prediction of learning outcomes. Accurate prediction, however, does not provide information on how to achieve the desired learning outcomes. Recent approaches emphasize an interdisciplinary design process using human-computer interaction and learning engineering methods. Accordingly, this paper introduces an adaptable assistance system for vocational education that is developed in an interdisciplinary collaboration between learning and computer science experts. The assistance system supports both the processes of self-regulated learning and collaborative knowledge building by enabling learners to individually choose from topic-specific and/or interaction-specific recommendations. The chatbot recommendations are derived from a learning suggestion middleware that evaluates xAPI statements. It is based on explanatory learner models that provide not only accurate predictions, but also interpretable and actionable insights into learners' activities and their learning process. A graphical knowledge structure provides an overview of the learning content, learner's progress and allows free navigation. Ideas on how to evaluate the assistance system in scenarios of self-regulated learning and workplace learning will be outlined.

Keywords: Technology-Enhanced Learning Environments · Vocational Education and Training · Intelligent Tutoring System · Recommendations · Chatbot

1 Theoretical Background

The acquisition of knowledge and skills that are flexible transferable to everyday (work) life plays a main role in vocational education and training (VET). In dig-

O. Viberg et al. (Eds.): EC-TEL 2023, LNCS 14200, pp. 618–623, 2023.
https://doi.org/10.1007/978-3-031-42682-7_51

ital learning scenarios at the workplace, Intelligent Tutoring Systems (ITS) [3] can provide valuable assistance towards boosting learners' skills and competencies. However, developing ITSs is very time-consuming and costly [4]. Therefore, this paper addresses the question how an low effort assistance system that individually supports learners can be designed. We present an adaptable assistance system that - in contrast to typical ITSs - allows learners to individually choose from topic-specific and/or interaction-specific recommendations in order to improve their learning. In this way, the effort required to develop the system can be reduced, while at the same time the possibility can be established to generate interpretable and actionable insights into learners' activities (see [4]).

The paper is structured as follows, Sect. 2 presents the psychological learning concept behind the system. Afterwards, Sect. 3 describes the realization of the conceptualized ITS. Finally, Sect. 4 outlines the planned case studies and concludes the paper.

2 Psychological Learning Concept

The psychological learning concept is based on different complex so-called *work-related learning tasks* that center learning on real-world work tasks and problems. These learning tasks model reality and aim at the integration of skills, knowledge, and attitudes [5]. Learners apply their knowledge and skills to fulfill the tasks. At the same time, they learn while completing the task(s) [5]. The *assistance system* is developed in an iterative process of design and improvement.

2.1 General Idea

A key part of the design process was to develop an explanatory learner model [4] that enables the insight-driven use of learning analytics to guide and improve learning in the learning environment. The explanatory learner model is based on the psychological Co-Evolution Model [2], which describes how knowledge is constructed through cognitive and social processes that mutually influence each other. As such, it provides the basis for deriving measurable indicators of knowledge-building behavior that is conducive to learning - both at the individual level and in shared knowledge construction (i.e. co-evolution of knowledge).

The idea of the project is to grant learners a larger degree of autonomy in regulating their learning process than it is usually the case with current ITSs. To this end, the system considers three control loops for learning regulation [1]: The *outer loop* establishes a connection between learners and the content demands of the learning modules. Learning modules combine work-related learning tasks of different degrees of complexity with information and media on a particular topic in the form of text, graphics, or video. The outer loop generates feedback on learning behavior and progress in a module. The *inner loop* generates feedback on learning behavior and progress for the individual elements of a learning module (e.g., on steps of a work-related learning task). In this way, learner's selection from the elements of a learning module as well as a deeper engagement with these

elements is supported. Finally, the *workplace loop* ensures that the assistance system can access digital components of the workplace to use its digital data for completion of a work-related learning task.

Taking into account these three loops allows to reduce the high overhead of AI-based ITSs as follows: Diagnostic learner information is obtained directly from the completion of work-related learning tasks whose solution steps are supported by the assistance system in form of a wide range of different information (e.g. solution examples, videos, feedback). Learners can choose from this information and learn which choice provides the best cognitive and motivational support.

2.2 Components of the Assistance System

To ensure the co-evolution of learners' knowledge as well as the regulation of learning via the loops mentioned above, the assistance system will consist of two essential elements: a) a structured visualization of the learning content, and b) opportunities for learners to interact with the system as well as with other learners.

Structuring and Visualization of Content. In order to provide learners with recommendations as to which learning modules are suitable for which learning objectives or which information can be used to solve different complex work-related learning tasks, the assistance system must access the content in a structured way. To this end, a polyhierarchical taxonomy can be used which facilitates a clear description not only of the content requirements of a particular learning module, but also of the work-related learning tasks. In addition, by explicitly defining the content necessary for task solution, the requirement profile of a particular learning task can be visualized via the taxonomy. Thus, the visualization provides a global orientation about the overall content as well as about the localization of the requirement profile of a particular learning task. Such a visualization can invite learners to consider how work-related learning tasks bridge separate learning modules and whether review or inspection of particular learning modules is necessary [8]. Furthermore, possible paths through a learning module can be represented in a manageable way.

Interactivity. Since work-related learning tasks are typically solved by a learner in several, qualitatively different steps, the assistance system will need to register the products a learner generates while performing these steps. In response, the assistance system can interactively support learners by, for example, providing them opportunities for collaborative exchange, explicating solution steps, providing further information, or by providing feedback. However, providing supportive information for improvement of learning such as formative feedback in real-time is one of the challenging tasks in technology-enhanced learning environments [6]. Recent research suggests that chatbots could serve as an effective means to empower students to actively control and regulate their learning process [7].

3 Technical Realization

Following the presented psychological learning concept, the ITS is conceptualized as a modular system with two components responsible for providing assistance. This architecture allows teachers to syntonize it to their individual scenarios by configuring components and even dynamically activating or deactivating them.

3.1 Chatbot Acting Proactively and Reactively

A chatbot is used to emulate an intelligent tutor with whom the learner can interact dynamically and who is able to bring together like-minded learners to collaborate on group tasks, for example. This virtual tutor can provide the learner with information as well as assistance such as suggestions regarding the learning process. The interaction can take place in two forms. The first is proactive, where the learner initiates the interaction by actively asking for assistance. An example of such an interaction scenario is that the learner has a certain time slot in which learning can take place and asks for learning content that is appropriate for the specified time with respect to the user's learning state. Second, reactively, in which case the virtual tutor reacts to learning actions that are indicators, with regard to the respective learning state, that the provision of assistance is appropriate. An example of such a trigger could be that the learner's navigation and interaction behavior deviates from a specified, psychologically grounded learning path. Accordingly, the virtual tutor would point this out and would suggest the learning action that would bring the learner back to the defined path.

As Learning Management System (LMS) we use the an open source project *ILIAS*[1] for authoring and presenting the learning materials and quizzes to the learners. The chatbot is implemented as a web application independent of ILIAS using *Botpress*[2], an open source framework for building conversational AI applications. The integration into ILIAS is done by a plugin, that is responsible for the communication with the Botpress server, where the functional logic is encapsulated and from where a suitable chatbot frontend is loaded.

3.2 Graphical Knowledge Structure

A graphical structure gives an overview of the learning topic, i.e. the knowledge structure. Its purpose is to visualize the learning content, the connections and dependencies between this content, and the learner's progress within it. Moreover, it serves as a means for the learner for navigation through the learning material, either freely or by following predefined learning paths. The learning material is, according to the ILIAS content structure, organized hierarchically with topics and learning modules as the top-level elements and *work related learning tasks*, as the leaf elements of the resulting knowledge structure tree.

[1] https://www.ilias.de/, visited on 03/06/2023.
[2] https://botpress.com, visited on 03/04/2023.

The current learning content is automatically loaded from ILIAS. Moreover, the teacher can use the graphical structure to parameterize the ITS, for example, by specifying, assistance scenarios in detail.

The knowledge structure component is implemented as a *Vue.js* application independent of ILIAS using *diagram-js*, an open source toolbox for building web-based diagram editors. The integration into ILIAS is done by a plugin, that is responsible for the integration of the JavaScript code into the ILIAS user frontend and for the communication with the ILIAS-core, e.g., for requesting the current learning content.

3.3 ITS Architecture

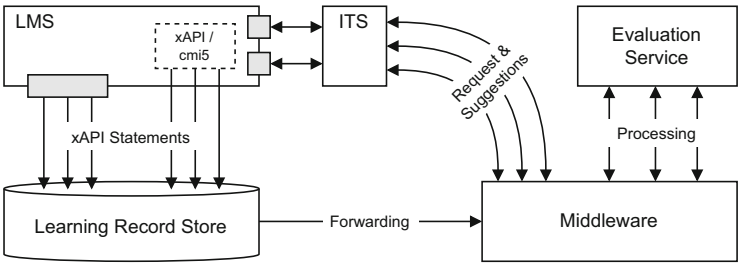

Fig. 1. Architectural overview of the ITS components and how they communicate.

The conceptualized ITS is implemented as an ecosystem of self-contained microservices as shown in Fig. 1. In this way, the intended modular character of the system is taken into account and the system is largely independent of version-specific changes in the LMS around which it is built (i.e., ILIAS). The interaction of the user with the learning content is either observed within ILIAS or within a connected *Content Management Systems* (CMS), depending on where the learning process takes place. The performed learning actions are sent as *xAPI* statements to a *Learning Locker* server[3], an open source *Learning Record Store* (LRS), for recording. From there, the statements are forwarded to a middleware component that is responsible for coordinating the ITS-side control of the user interaction components of the ITS. The middleware is a simple communication and information buffering component. The psychological concept is implemented by a second component, the *Suggestion Generator*, which is parameterized and invoked by the middleware. This component holds the psychological ITS concept, deduces the user's learning state from the incoming learning action statements, and initiates assistance actions when the processing of both in mutual dependence makes it seem appropriate. Using this architecture will not only allow to support different learning scenarios, which may include self-regulated or collaborative activities, but should also allow to transfer the approach to different learning environments.

[3] https://learningpool.com/learning-record-store/, visited on 03/04/2023.

4 Conclusion and Future Work

To summarize, the paper depicts the potential of an intelligent assistance system in digital learning environments in order to foster individual, self-regulated as well as collaborative learning processes. Future research should investigate the acceptance and effects of the assistance system in multiple scenarios of VET.

The assistance system will be tested in scenarios of self-regulated learning and collaborative knowledge construction as well as in scenarios, in which learners use digital tools to create themselves an interactive learning environment. The topics of the case studies will range from scenarios of continuing vocational training in the field of electrical engineering, workplace training in the use of CNC machines, to the training of interdisciplinary skills for the cross-company planning of automated solutions. Even though, preliminary results can not yet be presented, it is expected that the use of the assistance system will increase learner acceptance and engagement in technology-enhanced VET learning environments.

This allows us to provide a transferable tool that can help educators to develop and improve digital training programs with low effort as well as the learner to study more efficiently.

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Learning with the School Library: Mapping Technology-Enhanced Learning Underpinnings

Eduarda Ribeiro Mota[1,2(✉)], Teresa Margarida Loureiro Cardoso[1,3], Ana Carolina Ferreira da Cruz[1,2], and Filomena Pestana[1]

[1] Rede WEIWER®, LE@D, Laboratório de Educação a Distância e eLearning, Universidade Aberta, Lisbon, Portugal
904536@estudante.uab.pt, {teresa.cardoso,maria.coelho}@uab.pt, carolina.cruz@mail-rbe.org

[2] Rede de Bibliotecas Escolares, Ministério da Educação, Portugal

[3] Departamento de Educação e Ensino a Distância, Universidade Aberta, Lisbon, Portugal

Abstract. Technology-enhanced learning has been at the center of any global educational agenda for the past decades. More recently, with the COVID-19 pandemics, it has (re)gained a wider interest. However, it has been at the core of the Portuguese School Libraries Network since its creation in 1996, with the mission of promoting learning scenarios that enhance essential literacy skills for 21st-century learners. Therefore, in Portugal, the school library plays an important role in fostering such technology-enhanced learning environments. But, which underpinnings on technology enhanced-learning are evidenced in the main documents of the Portuguese School Libraries Network, namely in its *Learning with the School Library* Referential? The objective of our study is to map the underpinnings of technology-enhanced learning present in this framework, particularly in terms of how digital literacy is approached in relation to other literacies. To this end, we will use a qualitative methodology approach in a case study supported by content analysis with a focus on digital literacy. Ultimately, we will conclude that digital literacy is addressed transversally in the Referential, reflecting the innovative use of tools, technologies and learning environments to enhance students' literacy skills.

Keywords: School Library · Technology-Enhanced Learning · Digital literacy · Pedagogical Innovation · Collaborative Practices · Mapping K-12 Underpinnings

1 Introduction

In a pandemic context that has reinforced and accelerated the exponential use of technology in education, the inevitability of incorporating the digital component into pedagogical practices is widely recognised, with its implications for the definition of social and educational policies, which necessarily include the professional development of teachers with the intended impact of improving students' literacy. In Portugal, the School Libraries Network plays an essential role in this regard, contributing to the lines of action set out in the *National Digital Skills Initiative e.2030* [1], by promoting digital

O. Viberg et al. (Eds.): EC-TEL 2023, LNCS 14200, pp. 624–629, 2023.
https://doi.org/10.1007/978-3-031-42682-7_52

literacy among teachers, teacher librarians and students, reflecting the main guidelines of the *European Framework for the Digital Competence of Educators: DigCompEdu* [2] and the *Students' Profile by the End of Compulsory Schooling* [3], which is currently the main theoretical basis for the action of the Portuguese education programmes. It is, therefore, essential to analyse the foundations and guidelines of one of the main structuring documents of the School Libraries Network, of the Portuguese Ministry of Education, the *Learning with the School Library* Referential, showing how it reflects the creation of technology-enhanced learning environments and the promotion of digital literacy among students at all levels of education.

Thus, the main objective of our study is to map the technology-enhanced learning underpinnings perceived in the *Learning with the School Library* Referential, through a content analysis that allows us to contribute to the definition of the state of the art in Portugal regarding the action of school libraries in the promotion of learning scenarios that enhance the development of essential literacies for 21st-century learners, namely digital literacy.

2 Learning with the School Library: Strengthening the Curriculum Through a Literacy-Based Approach

2.1 The Conceptual Framework: Knowledge, Skills and Values

Since its publication in 2012 and its update in 2017 to include secondary education, the *Learning with the School Library* Referential has served as a strategic tool for improving the literacy skills of Portuguese students at all school levels. This guiding document is based on the assumption that the curriculum in all school years, from kindergarten to grade 12, is enhanced and enriched by its intersection with multiliteracies and it emphasises collaborative work between the teacher librarian and teachers of curricular areas in schools. It is grounded in a theoretical and conceptual framework that defines the knowledge, skills and values associated with three key areas of literacy – reading, media and information –, which are translated into descriptors of student performance at the end of each school cycle.

The performance descriptors are presented sequentially, given the 'progressive and cumulative nature of the knowledge and skills to be developed throughout the educational levels on which it focuses' [4]. With regard to digital literacy, it does not appear in the document as a specific area to which skills are linked but as a cross-cutting area to all the others, manifested both in the respective descriptors and in operationalisation strategies based on learning scenarios characterised by digital environments and the use of tools and technologies in formal and informal learning contexts. The descriptors associated with the expected performance are formally presented in tables that allow a sequential reading across school cycles within a literacy domain or a holistic analysis of the expected performance across the three literacy domains in each school cycle.

Alongside the tables of descriptors for the different literacies are the values and attitudes to be developed in each area of literacy, but, in this case, there is no division or sequence by cycle. For example, with regard to information literacy, there are nine attitudes/values that should be fostered at all levels of education, such as 'respecting

copyright and related rights', 'showing initiative and creativity in problem-solving' or 'accepting criticism' [4].

For each literacy area, a wide range of suggestions for operationalisation strategies is also provided, complemented at the end of the document with examples of activities to support teachers in developing these competences in their students in a strategic and integrated way in the specific context of their schools.

2.2 Empowering Students with Technology-Enhanced Learning

As mentioned above, the transversal nature of digital literacy is emphasised throughout the *Learning with the School Library* Referential, whose glossary defines digital literacy as 'the ability to use technologies, networks and digital tools ethically, effectively and safely to find, use, produce and communicate information' [4]. It is thus perceived across the different areas of literacy and is linked to the skills to be developed in reading, media and information literacy, in relation to the learning to be achieved in the curriculum areas in each cycle.

The focus on innovative learning scenarios involving digital strategies, technologies and tools is evidenced in the proposed operationalisation strategies at the end of each of the sections of the Referential dedicated to the three literacy areas. The analysis of these proposed strategies allows us to draw some conclusions:

- The diversity of purposes and educational contexts for using digital scenarios and tools is noteworthy;
- Some of the strategies are associated with only one literacy area, and it is possible to recognise the adequacy between the suggested strategy and the specificity of the literacy competence to be developed, e.g., the use of digital tools to improve reading fluency (reading literacy), media conversion activities (media literacy) and citation, referencing and bibliography (information literacy);
- Some of the strategies are common to two or more literacy areas, such as the collaborative creation of transmedia narratives, combining diverse languages, formats and media (reading and media literacy) or the use of digital book libraries, online catalogues, digital repositories, directories, search engines (reading, media and information literacy);
- Resorting to digital technologies favours strategies that involve operations of active use and elaboration, such as the creation of transmedia narratives or the production of concept/mind maps;
- In digital-based strategies, collaborative work is valued, either through the collaborative production of content or by encouraging participation in platforms such as wikis and blogs or participation in online reader communities;
- Some types of media, tools or multimodal products are suggested (e.g., podcasts, book trailers and citation management tools such as Zotero or Mendeley). However, even these are included as suggestions in lists that open up to other possibilities to be selected by pedagogical teams according to the class profile, the specific context of the schools and the objectives of the work to be developed with the students.

Our exploratory analysis also allows us to confirm that most of the proposals presented require the active involvement of students in their learning process, including, as

mentioned above, their participation in collaborative work processes. The implications for the teaching process are direct, namely for teachers, teacher librarians and other educators who are challenged to work together to design scenarios that promote meaningful learning activities for students in contexts that are increasingly hybrid learning ecosystems.

3 Designing Technology-Enhanced Learning Environments Through the Referential: Achievements and Limitations

The *Learning with the School Library* Referential, as of 2020, also counts on the online resource *Learning with the School Library: Activities and Resources* hosted on the official portal of the School Libraries Network [5], to complement its scope. This resource corresponds not only to a repository of activities and tools provided by the School Libraries Network Coordination Office to support the implementation of the Referential, but also to a virtual platform for interaction and exchange, where teacher librarians from all over the country can share their activity plans. Unsurprisingly, these plans are in line with those prepared by the Coordinating Office, as they have to follow the template provided and show that, regardless of the focus of the joint activity, teachers and teacher librarians favour collaborative work and implement active learning methodologies, with an emphasis on exploratory activities and experimentation, often framed in hybrid learning scenarios.

Collaborative practice is also at the core of the WEIWE(R)BE project, which is the result of a partnership between the School Libraries Network and the WEIWER® Network, based at the Laboratory of Distance Education and eLearning (LE@D) of the Open University (Portugal). This project, whose main objective is to develop the information literacy skills of secondary school students through the strategic articulation between the library and the classroom, also has the *Learning with the School Library* Referential as one of its main frameworks, focusing on aspects related to information literacy and to the transversality in the approach to digital literacy [6]. Furthermore, this is a project that has had as technical and pedagogical support an ongoing training course aimed at teachers who take part in the project in its first year of implementation, allowing their monitoring in the field, as well as the sharing of experiences, practices and resources, mainly through the LMS platform used in the training course. The participation of each school in the project involves the development of a work plan corresponding to a practical learning situation, designed in collaboration between the teacher librarian and at least one teacher of a curricular area, relying on the operationalisation strategies recommended in the *Learning with the School Library* Referential. In their work plans, most schools opt for collaborative work and active learning methods supported by digital environments and tools.

Notwithstanding the achievements presented above, and taking into account the national coverage of the libraries network, the comparative analysis of the monitoring reports on the implementation of the *Learning with the School Library* Referential in recent years shows a decrease in the number of school libraries implementing it in 2021–2022, namely: 1601 (out of a total of 2525) compared to 1824 (out of a total of 2469) registered in the pre-pandemic school year [7, 8]. However, in terms of the impact

of implementing the Referential in schools, teachers' perceptions maintained the same trend of perceiving a significant impact on learning and educational success, with the agreement with this perception ranging from 96%–98% in 2018–2019 [8] to 97%-99% in 2021–2022 [7].

Apart from the fact that the number of participating schools is lower than before the pandemic, which could be explained, for instance, by the extraordinary workload that we all had to face, the teachers' perceptions of the impact of the Referential reveal the need to invest in the literacy-approach to the curriculum that this framework entails and, consequently, highlight the need for more teacher training as a means of promoting the implementation of the Referential in more schools across the country. In response to this need, the School Libraries Network published the guide *Learning with the school library: a programme for developing literacy* [9] to support teachers in developing a strategic, systematic and comprehensive approach to applying the Referential in their schools.

4 Conclusion

Given the challenges facing education in today's world, characterised by the ubiquity of digital technologies and a high degree of uncertainty about the future [10], education systems must define policies that encourage pedagogical innovation. In the case of the Portuguese education system, the School Libraries Network programme has contributed to a dynamic of innovation in schools by relying on teacher librarians to apply in their local contexts the national guidelines, which focus on a literacy-based approach to the curriculum that integrates learning with multiple literacies. Through the national coverage of the libraries network, a significant number of schools have applied the *Learning with the School Library* Referential, whose conceptual framework and suggested practical activities have enabled the implementation of technology-enhanced learning based on active learning methodologies and centred both on collaborative work and the strategic mobilisation of digital environments and tools, thus contributing to the digital empowerment of both students and teachers.

Considering, on the one hand, teachers' perceptions of the positive impact of the activities of the Referential on students' learning and educational success and, on the other hand, the recent decline in the number of schools implementing it, it is essential to ensure that its implementation in schools becomes even more comprehensive, integrated and systematic. Ultimately, this is also due to the fact that digital literacy is a transversal literacy that reflects 'the presence of technologies, tools and digital environments in all contexts and domains, formal and informal, of learning' [4].

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