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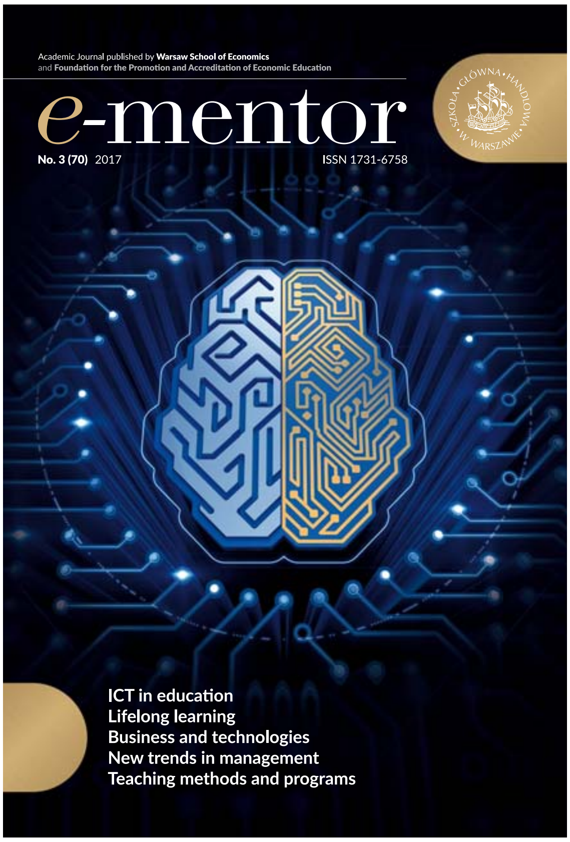

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The different dimensions of widening access to virtual scenarios in the WAVES project

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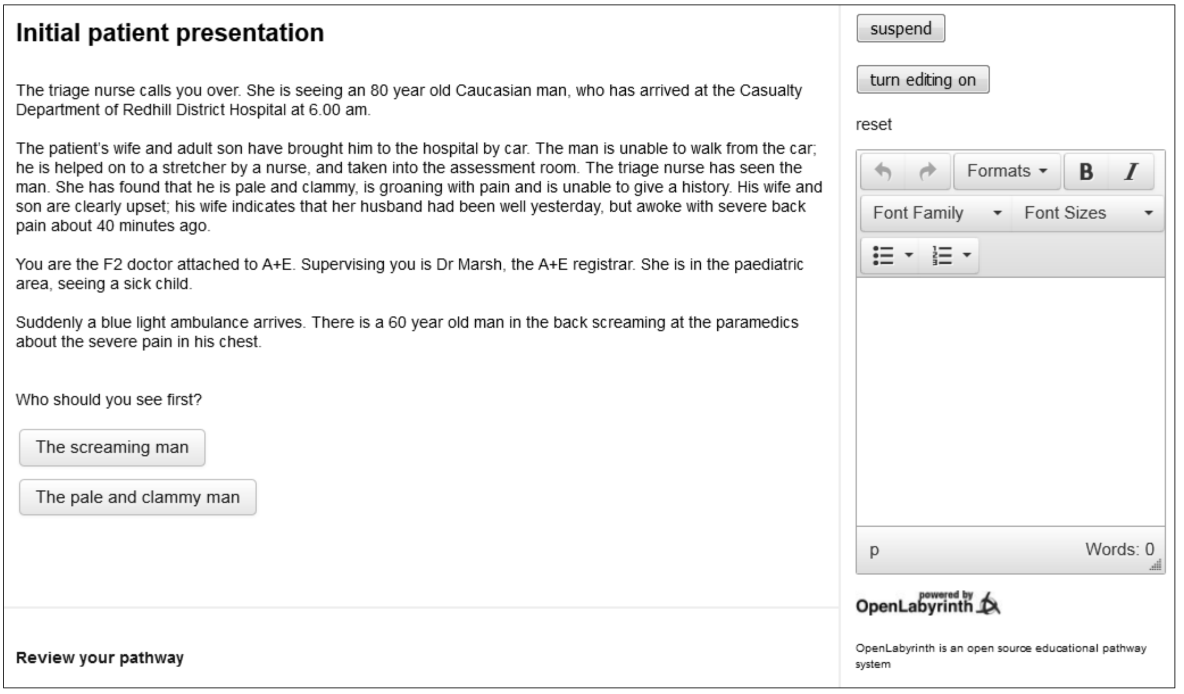
Learners welcome practice-oriented environments that promote learning by experience, rather than those that explicitly give them rules to memorize. Yet, many educators believe this form of instruction is unattainable for them and their students. The aim of this paper is to demystify the concept of virtual scenarios, which are a form of e-learning resources used in scenario-based learning. This is presented in the context of the WAVES project, an ERASMUS+ initiative aimed at widening access to virtual scenarios. This article presents ways to simplify the design and use of scenario-based learning resources. This project is open to community participation, and the authors intend to help popularize virtual scenarios and to make e-learning courses more varied and attractive.

Educators planning e-learning activities can use a wide collection of instructional designs. Clark and Mayer proposed classifying these into three architectures of instructions: receptive, directive and guided discovery architectures (Clark & Mayer, 2008, p. 27). Receptive designs focus on the presentation and transmission of educational content to learners, using online lectures or videos. When following directive instructional designs, the educational content is divided into small chunks of knowledge, which are first introduced as rules, and then as examples that can be followed and practiced. Immediate feedback to instantly correct undesirable outcomes is then provided. This type of instruction is very common in procedural training or computer adaptive learning, where learners are involved in frequent formative assessment, in the form of quizzes. The premise of discovery learning is that educators design an environment in which the learners will be able to construct their own knowledge. Research results show that pure discovery learning is inefficient, as a high level of unaddressed confusion may arise when learners are left to master a new learning objective unaided (Kirschner, Sweller, & Clark, 2006, pp. 75–86). However, this problem may be remedied when carefully chosen guidance is introduced into the discovery environments (Alfieri, Brooks, Aldrich, & Tenenbaum. 2011, pp. 1–18). Guided discovery approaches include project-based learning, simulation-based learning, game-based learning, etc. These terms are often interpreted differently, and the boundaries between them are blurred, so there is little definitive consensus on the characteristics of each approach. It goes beyond the scope of this paper to resolve those conflicts. The intention is rather to focus on features characteristic to a particular type of guided discovery learning called scenario-based learning (SBL). Recently, the use of this term has been promoted through a book by Ruth Clark entitled "Scenario-based e-Learning" (Clark, 2013, p. 5). It is important for SBL activities to cast the learner in a job-realistic situation that requires collecting information on a problem, taking action, and reflecting on the reactions of the environment. This differs from game-based learning, by focusing on particular problems to be solved without the competitive elements encountered in games. Computational simulation, which is understood as dynamic mathematical models embedded in e-learning environments, may be part of SBL resources but is not a compulsory component. SBL leverages both group activities common in problem-based learning and self-directed learning.

Virtual scenarios

Virtual scenarios (VS) are electronic learning resources applied in SBL. A common implementation of VS in healthcare sciences are virtual patients (Cook & Triola, 2009, pp. 303–311) but their use need not be limited to medicine. The scenarios may focus on other subjects of job-relevant tasks, like virtual clients for lawyers or bank loan applicants, or even objects like virtual cars for repair, or virtual test tubes with content to be identified. The authors understand the term "scenario" as a situation that may happen in the workplace. The steps in a scenario can be triggered by learner actions or be time-driven. A scenario may be a linear chain of events or branched events; there may be several routes through it, depending on the learner decisions made. Navigation interfaces may consist of hyperlinks to follow, hierarchical menus of items to select, clickable full-screen active objects, or virtual worlds to explore (Clark, 2013, p. 57). The data presented in a scenario usually starts with a job-relevant trigger that engages the learner to take action, and proceeds to the analysis of a set of case-related

Figure 1. The start screen of a virtual scenario in the system OpenLabyrinth



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data that is presented in a way that mirrors real life, and that may need to be retrieved or synthesized by the learner from the environment itself. Feedback may be classified into instructive (i.e., correcting particular actions) or intrinsic feedback (i.e., showing consequences of action to be interpreted by the learner). Intrinsic feedback, in particular, is a key component of SBL activities, while mechanisms to support reflections on the problem-solving tasks and feedback received are crucial elements of effective VS. Figure 1 shows the initial screen of an instance of VS in the OpenLabyrinth system in use at St. George's, University of London.

The WAVES project

WAVES stands for Widening Access to Virtual Educational Scenarios, and is the name of a project co-funded by the ERASMUS+ framework (The WAVES project, http://wavesnetwork.eu). The project partners come from across Europe and include both academic (the project coordinator St George's, University of London; Karolinska Institutet, Aristotle University of Thessaloniki, and Masaryk University) and corporate partners (Bayer plc and Instruct AG). Additionally, the project is supported by a community of associated institutions located in many countries outside of Europe. The project began in 2016 and will run until the end of 2018.

The goal of the project is to increase the use of VS by streamlining workflows in existing authoring software and providing guidance to the wider community about how to design effective SBL content. The primary target group for WAVES is educators, since they determine the instructional design that will be used in teaching and produce SBL educational content. However, we cannot address their needs without also considering two other entangled stakeholder groups: students and educational technologists. As system end-users, educators have little interest in detailed technical issues and require a VS authoring system to be both user-friendly and produce learner-friendly scenarios. Such improvements in software tools are often made by enhancing application programming interfaces (API), which, while technical in nature, are transparent to end-users, and enable new functionality to be delivered.

SBL is not about a particular technology and its implementation can range from a clever use of hyperlinks in Microsoft PowerPoint, to the use of virtual world environments (Clark, 2013, p. 12). The use of a specific tool does not automatically guarantee that the outcome will involve VS, as defined by SBL methodology. Technically complex SBL environments have their merits, but their use may not always be more effective than simpler technologies (Dankbaar, Alsma, Jansen, van Merrienboer, van Saase, & Schuit, 2016, pp. 505–521). It is also true that the design of technically complex resources, as established in contemporary video games production, is a highly resource-intensive process that requires collaboration from specialists in many disciplines. WAVES takes an alternative stance by empowering individual e-learning enthusiasts who are keen to use SBL for design and to use VS in their organizations, even in low budget settings. The VS in Figure 1 is presented using very simple technical means: just a text description and two options. It could be easily enhanced with high quality video clips or an impressive 3D environment, provided the right budget, but this does not change the instructional design behind it. The major shift happens when there is no directive voice saying "you should do this", as is present in lectures or tutorials, but instead the student makes an independent decision and experiences what changes it brings in the simulated environment. WAVES aims to show that it does not require a film director or specialist in artificial intelligence to make this shift in education.

The outputs from WAVES are organized into two toolkits: knowledge and technical. These serve to show the open-ended nature of the project, delivering a wide range of ancillary resources or mechanisms that welcome community engagement. The knowledge toolkit contains a spectrum of resources that are directly useful for educators, including tutorials, best practice guidelines and examples promoting the methodology behind VS. This will culminate with a MOOC on SBL organized on the FutureLearn (https://www.futurelearn.com) platform in spring 2018.

The WAVES technical toolkit involves changes or enhancements of the existing VS systems to make them more accessible and usable for educators. By a VS system, we mean a suite of integrated tools, including an authoring component that enables teachers without a detailed technical background to create VS, a player to display the VS to selected groups of learners, user management panels and some basic analytic tools. The developments will focus on two VS systems: the open source project OpenLabyrinth (http://openlabyrinth.ca), led by David Topps from University of Calgary, and the established system CASUS (http://www.instruct.eu/en/casus-software), maintained by Instruct AG, a spin-off company initiated by LMU University of Munich. All improvements included in the toolkit will be implemented in these software products.

OpenLabyrinth is a web application developed in PHP. VS in OpenLabyrinth are branched. Screen cards that reflect each stage in the executed scenario can be extended by different question types, counters, timers and multimedia content. A set of extensions for the system is available, including the use of Semantic Web technology to describe the content of VS for later automatic discovery and retrieval (Dafli, Antoniou, Ioannidis, Dombros, Topps, & Bamidis, 2015, pp. e16), and a module for human-computer hybrid interfaces (Topps, Cullen, Sharma, & Ellaway, 2016, pp. e1659v1). The current version of OpenLabyrinth is 3.4, but a new version 4 is in development, with a modified architecture of the source code. Starting with version 4, the official name of the system will be shortened to Olab.

CASUS is a web application developed in Java (Hege, Kononowicz, Pfähler, Adler, & Fischer, 2009, pp. 51–55). VS in CASUS, unlike those in OpenLabyrinth, do not branch. Instead, a diverse set of activities corresponding to every stage of the scenario is permitted (e.g., selecting options from long menus with hundreds of items to prevent answer bias, taking advice from experts, or judgment of individual results in diagnostic tests). There are also tools that are independent of the navigation between the screen cards (e.g., taking notes on observations). CASUS offers a rich set of tools for user management, exposure of VS in courses (e.g., permitting spaced activation [Maier, Hege, Muntau, Huber, & Fischer, 2013, p. 45]) and summative, controlled electronic exams.

OpenLabyrinth, as a publicly available, free of charge software product, can be used by anyone who follows the WAVES project. The changes implemented in CASUS will benefit current users and make the product available to new markets. We also hope that the lessons learned while developing these enhancements (i.e., technological know-how that will be shared by the project) will simplify introducing desired changes in other VS systems that are not part of this project.

The technical toolkit

In accordance with the design-based research methodology (Wang & Hannafin, 2005, pp. 5–23), the development and research in the project proceeds through an iteration of probing user needs and implementation phases. The project started with a survey, and a series of semi-structured interviews and focus group discussions among the associate and dissemination partners. The resulting user stories were prioritized in an agile card sorting process, with detailed results presented in a report by Schwarz and Kavia (2017, pp. 65–70). These general user requirements have been transformed by the WAVES technical reference group into three types of concrete tasks: improvements to accessibility, improvements to usability and improvements to integration. These are presented in more detail in the following two sections, as well as in Figures 2 and 3.

The tangible outputs included in the technical toolkit will be, depending upon the nature of the development task, a set of branches to existing open source projects or initiated new small projects in public code repositories as GitHub (https://github.com); graphical designs as wireframe models or templates; and technical reports describing proposed improvements. These outcomes will be handed over to the software partners maintaining the code of the two reference VS systems (OpenLabyrinth & CASUS) and made available via the project's website.

In the development process, it is important to consider the plans of the organizations that control the VS software code. For instance, OpenLabyrinth is now undergoing a major architectural shift from a monolithic to a microservices-based architecture. While this represents a great opportunity to influence change, it also contributes to a state of uncertainty on the final shape of the system and, to a certain degree, an inability to test proposed developments. This project has to work within the time and resource constraints allocated to the technical toolkit. For these reasons, the project consortium has decided not to undertake significant back-end changes, and instead focus on extensions to the presentation layer and developments of loosely coupled modules and services for both CASUS and OpenLabyrinth.

Accessibility and usability enhancement

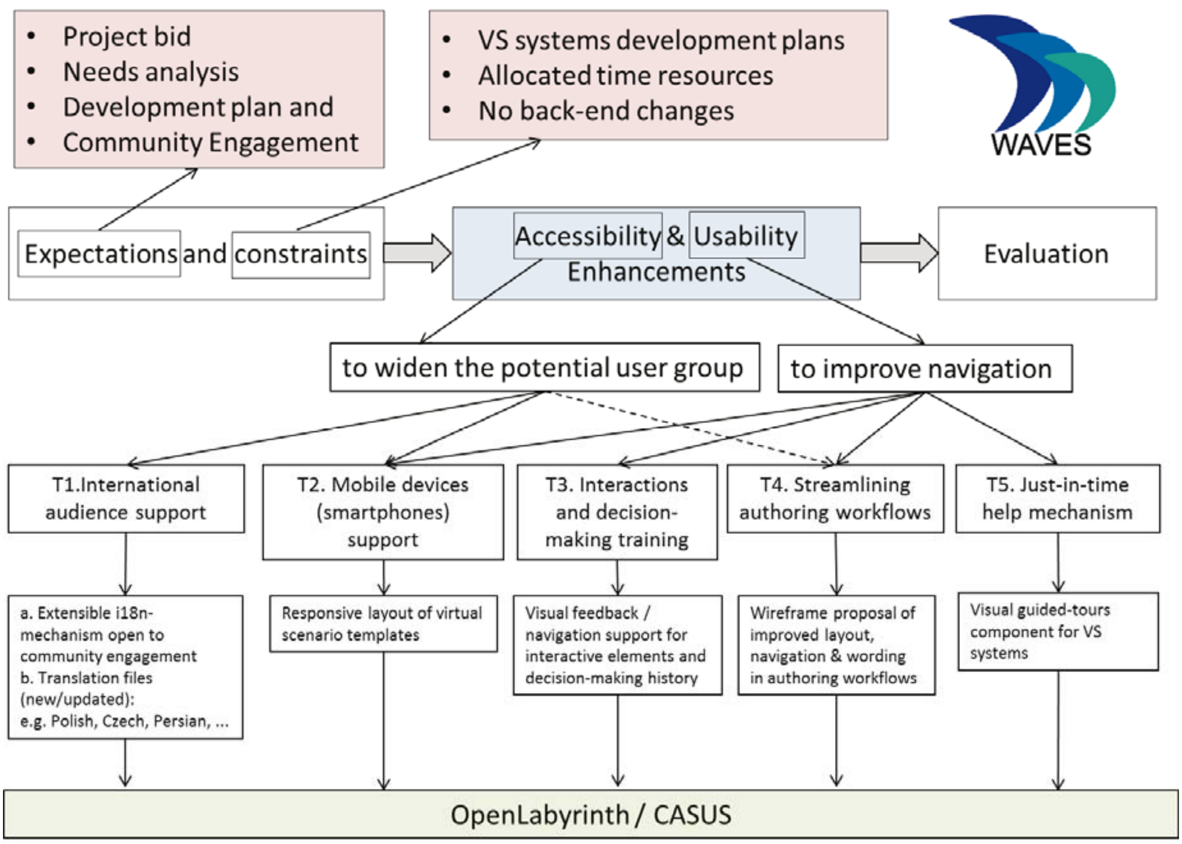
Figure 2 presents an overview of five development tasks around accessibility and usability within the WAVES project.

Accessibility is often identified as web accessibility, as understood by the W3C Web Accessibility Initiative (WAI). This empowers users with different forms of impairment (e.g., sight or hearing disabilities) to use and author web content (e.g., by enabling the use of assistive technology as screen readers). In WAVES, this term is understood more broadly to include any means by which the potential user group may be widened. This understanding encompasses internationalization (i18n) efforts that enable the community to prepare different language versions of VS user interfaces (task T1, Figure 2). The necessary measures may include separation of the user interface text into property files, adequate character encoding, alignment of interface elements where international differences occur e.g., in right to left languages (e.g., Hebrew or Persian), etc. The implementation of these changes is supported by i18n guidelines and mark-up rules (e.g., W3C Internationalization). Related to this task is construction of community engagement tools for translation, which could include crowdsourcing and open APIs (like Google Translation API) to accelerate translation and using different organizational forms to sustain and improve quality of the translations.

The results of the WAVES needs analysis showed that more than half of respondents want to use VS on small mobile screens (Schwarz & Kavia, 2017, pp. 65–70). A potential barrier to that are static user interfaces. Improvements used in task T2 (Figure 2) involve not only mechanisms to make the layout of elements scalable (responsive), but also more selective for mobile learners. The problem is addressed by building a collection of layout templates for user interface elements, which could be used by scenario authors, depending on their needs.

Usability is often considered the "ability of the user to use [a] thing to carry out a task successfully" (Tullis & Albert, 2013, p. 5). WAVES focuses on the simplification of common workflows as encountered during the authoring and use of VS. The project has agreed on a set of common use cases (e.g., "Author creates a short branched VS with one decision point" or "Instructor wishes to know who in the group of students has completed a VS"). These are

Figure 2. Overview of accessibility and usability enhancement in the WAVES project



Source: own study.

now analyzed using users with limited experience of VS authoring, to arrive at wireframe models of a streamlined layout (T4, Figure 2). Within this activity, the consortium also reviews the workflows from the perspective of usability heuristics: in our case, we used Jakob Nielsen's ten usability heuristics (Nielsen, 1995). Additionally, we take into consideration the web accessibility guidelines developed by W3C WAI (https://www.w3.org/WAI) – e.g., Web Content Accessibility Guidelines – WCAG – or Authoring Tool Accessibility Guidelines (ATAG).

Task T5 (Figure 2) further simplifies the design of VS by adding a visual guided tour mechanism to the authoring tools. Such guidance, which is currently being implemented using the Intro.js library (http://introjs.com), enables a step-by-step introduction for novice educators to individual elements of the user interface, which is displayed as a semi-transparent layer on top of the regular user interface in a web browser.

Finally, task T3 (Figure 2) focuses on the intuitiveness and functionality of user response elements in VS. This means, for instance, corrections of usability issues when displaying feedback to response options (e.g., in multiple answer controls) or support for reflection when reviewing the data obtained and the choices made throughout the scenario. This task is especially interesting in branched scenarios in which the navigation graph may be complex. The topic of visual learning analytics has been preliminarily researched by one of the authors, in the context of MOOCs with integrated virtual patients (Kononowicz, Berman, Stathakarou, McGrath, Bartyński, Nowakowski et al., 2015, p. e8), and is investigated more in depth by WAVES, by building more universal and lightweight tools.

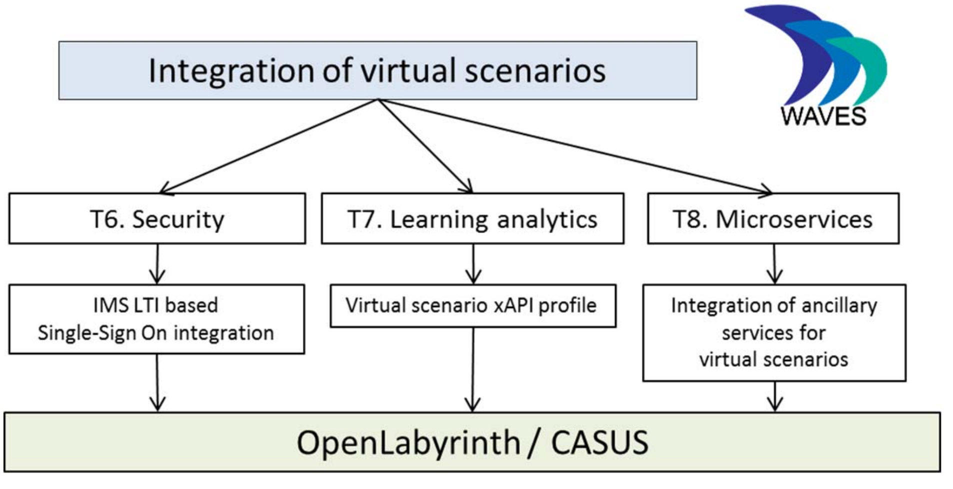
Integration of virtual scenarios

Integrations needed by VS system users are divided in three categories: security, learning analytics and the formation of microservices (Figure 3).

The WAVES development activities with respect to security (T6, Figure 3) aim to solve the frequent problem of e-learning users who need to memorize many login credentials. WAVES focuses on the existing Learning Tools Interoperability (LTI) specification (https://www.imsglobal.org/activity/learning-tools-interoperability), developed by the IMS Global Learning Consortium. LTI offers a single-sign on mechanism that enables adding VS as an activity to learning management systems (LMS) and MOOC platforms, without the need for separate authentication. The consortium members' initial experience with this topic (exemplified by the integration of OpenLabyrinth into the OpenEdX platform [Stathakarou, Zary, & Kononowicz, 2014, p. e672]) is now transferred to extensions of other VS systems (CASUS) and generalized by tests of the existing implementation with different LMS (Canvas [https://www.canvaslms.com], Moodle [https://moodle.org] and FutureLearn [https://www.futurelearn.com]).

Learners leave many traces of activities while experiencing SBL content. In the age of big data and analytic techniques, the community expects to use log data in order to optimize the learning process. Data locked in proprietary systems represents a barrier to access, but a solution to that is to broadcast events in an e-learning infrastructure. The specification often used for this purpose is Experience API (xAPI, https://github.com/adlnet/xAPI-Spec). The assumption is each of the learner's basic activities (e.g., opening an educational video clip) will generate an xAPI statement. According to the technical specification each statement is a type of formalized log entry which must have at least three components: actor, verb, object – e.g., "John opened this video". These statements can then be captured by registered dedicated services, called learning record stores (LRS), and be enabled for analytic processes, either with tools integrated in the LRS or exported elsewhere (e.g., to performance dashboards in LMS). Examples of LRS include tools like Learning Locker, Watershed LRS and ADL LRS. Since many e-learning

Figure 3. Integration mechanism of virtual scenarios in the scope of WAVES



Source: own study.

tools support xAPI statements, this infrastructure will enable a broader analytic view of learning processes. The constraints imposed by the xAPI specification are loose: e.g., anyone can propose new verbs or data structure for the actors or objects. The efficient use of xAPI for learning analytics requires more standardization in order to clarify the use of individual elements of statements, which are achieved using application profiles. The WAVES project contributes to that effort by supporting the MedBiquitous Learning Experience group (https://www.medbiq.org/learning_experience) in their task of building profiles for VS and virtual patients (T7, Figure 3). The constraints discussed include the required structure of information in the learning activities descriptions, which represent objects in xAPI statements, and the semantics of verbs recommended by the profile. This will enable aggregation and analysis of user experience data produced by different SBL tools. In this task, the consortium demonstrates how to build a learning analytics infrastructure that consists of a VS system connected to a LRS and analytic tool to enable educators and learners to discover more about the processes happening in SBL activities.

Finally, WAVES promotes the current trend of converting monolithic architectures into sets of microservices and demonstrates how this applies to VS systems (T8, Figure 3). Following the microservice paradigm, a VS system is reduced to the basic core functionality with many optional components that can be plugged into the system when needed. Inga Hege developed an exemplary microservice that extends the VS systems' core functionality (Hege, https://github.com/clinReasonTool/ClinicalReasoningTool). This microservice is a graphical tool based on a concept-maps approach and is displayed next to the main screen of the VS. While the learners proceed through a scenario, they may note their observations, hypotheses and plans, and show graphically how those relate. Learners' input into the tool, showing their reasoning process, can be then compared with an experts' answer for feedback (Hege, Kononowicz, Nowakowski, & Adler, 2017). This tool will be integrated in both reference VS systems of WAVES (OpenLabyrinth and CASUS) using a RESTful API.

Discussion

Ideas around VS and SBL can be traced back under different names across many years of research on instructional design. Yet the dissemination and usage of this method in education is not as widespread as might be expected, considering its established merits. WAVES is attempting to remedy this by providing methodological and technical toolkits with the aim of widening access to this form of instruction.

For instance, usability testing and improvement is crucial for software development and is recognized by major players in the mass market. However, usability is often neglected in academia, where the emphasis is instead on innovation and the pragmatic achievement of stated objectives, even though this can often come at the expense of user-friendliness. Within WAVES, developers and advanced users of VS software step back and explore how they can simplify authoring workflows for educators who are interested in using VS in their teaching.

Accessibility is often understood as being limited to compliance with formal specifications, such as WCAG. Such standards are without doubt very useful, benefitting not only those with disabilities but also reducing the cognitive load and improving flexibility in general usage. But beyond that, WAVES aims to widen access to other groups of potential users (both educators and learners) that might have encountered barriers, such as language or limitations of their mobile devices. It is important to distinguish between the accessibility of the authoring tool and the accessibility of content the authoring tool is producing. For instance, WAVES focuses on extending the authoring tools to enable teachers to produce VS for mobile devices, such as smartphones or tablets. Supporting teachers to design their VS on smartphones is not within the scope of the project and, in the opinion of the authors, is unlikely to be useful. On the other hand, i18n efforts or usability enhancement pertain also the authoring tool itself to enable easier navigation in the VS editors for the educators.

Different integration mechanisms considered in the scope of WAVES address the fact that SBL software tools are not self-standing artifacts and should fit into existing IT infrastructure. One of the authors of this paper discussed integration mechanisms of virtual patients in a paper published in E-mentor in 2010 (Kononowicz, Hege, Adler, de Leng, Donkers, & Roterman. 2010, pp. 82–86). It is interesting to follow how the mechanisms popular at that time (e.g., AICC HACP, SCORM RT or MedBiquitous Virtual Patient) have changed in recent years. The methods introduced in this paper (e.g., LTI, xAPI, RESTful interfaces) are more lightweight, and move away from transfer of content between systems and towards the integration of services.

Many of the project partners in WAVES have a background in developing VS in medicine. This should not be surprising, as healthcare science has a long history of simulation and the innovative use of technology in education. Yet, there is no reason the tools discussed here could not benefit the wider community. Indeed, systems such as CASUS have already been used in law sciences and biochemistry. The mechanisms on which the tools are built, such as the construction of a state graph for VS, are present in many types of guided discovery approaches, including game-based learning. The increasingly modular architecture and the idea of exchangeable layout templates enable the creation of bespoke solutions for individual disciplines, using the same scenario-based engine.

WAVES has recently reached its halfway point and the final outcomes are still yet to emerge. The release of the toolkits is planned to occur by the end of the project in 2018. Authors of this paper would like to invite the readers to follow the project's activities and engage in the use of VS in their teaching and training.

The experience of WAVES might also motivate those who develop their own VS or more general e-learning software to reflect on the question of how accessible their tools are for their target users.

Conclusions

In this paper, we have summarized the concept of virtual scenarios as often used in scenario-based learning. The WAVES project, as presented above, aims to disseminate knowledge about this form of learning and promotes it by simplifying access to VS systems. Our intention was to show the diverse range of tasks that can be related to improving accessibility, using the example of WAVES project activities.

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The different dimensions of widening access to virtual scenarios in the WAVES project

Background: Virtual scenarios are e-learning resources that present job-realistic situations, promote taking actions and provide learning via the consequences of decisions made. The WAVES project attempts to widen access to virtual scenarios for educators and learners.

Aims: The aim of this paper is to present different facets of simplifying access to virtual scenarios that structure the developments in WAVES.

Methods: The developments are driven by user needs and shaped by a technical reference group to follow current trends in information technologies. They also meet the constraints of the legacy code of two exemplary authoring systems (OpenLabyrinth and CASUS) and fit the limits of allocated time resources.

Results: The paper characterizes eight tasks that address accessibility, usability and integration challenges related to virtual scenarios. These involve enhancements in such topics as internationalization, responsiveness, streamlining of workflows, just-in-time guidance, support in interaction and reflection, single sign-on security, learning analytics and microservices.

Conclusions: The authors describe the features characteristic to scenario-based learning and outline development directions to improve access to virtual scenarios. The examples demonstrated using two authoring tools are intended to influence improvements in similar e-learning systems.

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