A Smart Ecosystem for Learning and Inclusion: An Architectural Overview

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Abstract. In recent years, open educational resources have been offered in initiatives that aim to reach a wider audience, contributing to the democratization of knowledge. However, there is still a gap with regard to the accessibility of these educational resources. In this sense, this paper presents a digital ecosystem architecture, called SELI (Smart Ecosystem for Learning and Inclusion), which is being developed by a group of ten countries in Europe and Latin America. This ecosystem can be viewed in four different views (philosophical foundations, supporting infrastructure, concept and service bus). It aims to provide an accessible learning environment, involving recent technologies such as Blockchain, microsites and the use of universal accessibility guidelines.

Keywords: Smart ecosystem · Inclusion · Architectural model

1 Introduction

There are a large number of people who are disadvantaged in the current educational environment due to several reasons among which are archaic educational environment, pedagogy, methods and goals, lack of creativity in the current system, insecurity, economic, and social issues, etc. [1]. The needs of the disadvantaged groups, such as

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immigrants, homeless, physically challenged such as the blind, hearing impaired, and other disabilities are not readily considered in the modelling, design and development of learning environments.

Building a learning ecosystem that is smart has been the objective of many academics over the past years. A lot of research effort was engaged incorporating the followings in the educational environment to support the aspiration of teachers and students: artificial intelligence techniques [2], recent technology such as blockchain and microsites [3, 4], open and active pedagogy such as global sharing, digital storytelling [5]. According to [6], "technologies should not support learning by attempting to instruct the learners, but rather should be used as knowledge construction tools that students learn with, not from". In line with [6], we consider the building of technological and pedagogical hub consisting of several tools and services to support the teacher's role of guidance, mentoring, and creativity and support student's role of knowledge seeking, construction and learning.

In our opinion, one way to achieve a solution to address the global yearning for inclusive and personalized learning is by crafting more potent and supportive innovation through technologies, pedagogies and novel conditions for learning. In fact, a smart learning environment can only be achieved when all the services and tools that we developed in this work are properly configured and aligned with the needs of the users.

This study therefore presents the architectural composition and design of all the tools and services available within the smart learning ecosystem. An aspect of the solution will show how a learner centered pedagogy such as digital storytelling and recent technologies such as blockchain and microsites have been implemented according to the universal accessibility standard [7], within a smart learning ecosystem to provide the much-needed learning support especially for the disadvantaged groups, but also anyone. Other aspects of the learning ecosystem are authoring services, learning management system (LMS) and content management system (CMS) services, and learning analytics services.

Being an integrated ecosystem, the solution presented in this paper will address some of the needs of the disadvantaged groups in the educational settings. Furthermore, the overall aim of the learning ecosystem is not only to inspire teachers but to provide cohesive learning support, realizing learning functions, providing learning contents and ensuring that all individuals within the learning ecosystem attain the full learning potential. The implementation of this novel ecosystem is covered under the auspices of EU-LAC project entitled, SELI.

2 Background

2.1 Smart Ecosystem

In general, an ecosystem is a community network of interactions between organisms and their environment [8]. According to [9], the term "smart ecosystem" describes a wide range of concepts, from networking architecture to service-based software

solutions. The most frequent references to the smart ecosystem come from Artificial Intelligence research related to complex systems, including the biological ones [10].

The smart ecosystem is a mimic of biological ecosystems [9]. Thereby a smart ecosystem conforms several software applications and components which satisfy the properties of being robust, scalable, and self-organizing.

The smart ecosystem, like biological ones, consists of Agents, Populations, and Habitats. An agent is software and data able to move from one computer to another in an autonomous way keeping the ability to continue executing. The agent, as software, does not move but it gets copied from one computer to another; of course, including data. It is the behavior of agents to migrate in a biological ecosystem. Each software participant is considered an agent in a smart ecosystem. It is a piece of software that acts, for a user in a relationship of agency, autonomously in an environment to meet its designed objectives [11]. The habitats are the nodes of the smart ecosystem. Its function is analogous to the ones in the biological ecosystem. A node is related to a user computer or server in the network with agent station properties. The populations are represented by the agents migrating between habitats. An agent will use a context on each habitat. The context defines an environment with primary data relevant to the applications; it is called an entity and can be software, sensors, services, intelligent objects connected to the habitat.

The concept of a smart ecosystem has been used in education for several years to describe environments for production, reuse and adaptation of content [12]. However, with the development of technology, notably blockchain, this concept has evolved into a smart ecosystem characterized by being an open community, where there is no need for centralized control. In a smart ecosystem there is no leadership structure in response to the need of the dynamics of the environment. A smart ecosystem trusts open coding and the incorporation of systems based on their aggregation, incubation, and facilitation.

The essential components of a smart ecosystem are infrastructure, services and users.

Users are part of learning communities, that can be individual or groups of individuals interacting and collaborating synchronously or asynchronously.

Services are the support for learning involving content management, pedagogical aspects, and instructional design. It includes, for example, learning content management system (LCMS), learning management system (LMS), content distribution system (CDS), recommendation system, digital libraries, learning analytics component, social networks among others. The work of Normak, Pata and Kaipainen [13] highlights that the impact of learning ecosystems on the pedagogical aspect is different from that produced by virtual learning environments. They point out that while in a virtual learning environment (LVE), the teacher foresees the activities their students must perform, in an ecosystem the activities to be carried out spontaneously during the course due to the interactions between students-tutors, students-material, students-technology, tutors-technology. In the LVE certain pedagogical paradigms are fixed and embedded in the instructional design before the realization of the course. In contrast, the interaction between students and facilitators causes the evolution of the pedagogical paradigms in a smart ecosystem. One of the challenging research topics as raised in [14] is to specify how to establish pedagogical paradigms in learning ecosystems.

Within the framework of learning ecosystems, there is a disagreement between the principles of self-regulated learning, which indicates that students must be independent, autonomous and self-directed. Their learning should arise from their interests and from situations that are meaningful to them, interacting with other students, also acting as teachers of others and participating in communities.

The infrastructure is based on web services or microservices capable of being interoperable. It will enable the traceability of the processes to be maintained while maintaining the security and confidentiality of the data. An example of interoperability can be seen among Google, YouTube, Facebook, Amazon Web Services, among others, where it is increasingly natural to move from one system to another sharing information.

Because of these qualities, one of the technologies that is gaining more followers for digital learning ecosystems is the blockchain [15, 16].

2.2 Open Educational Resources

Openness in education has originated in popular movements to democratize access to knowledge and to improve and equalize access to quality educational content to all people. Although it is not a new concept the idea of open education has increasingly become associated with digital content and practices [17].

In 2002, UNESCO coined the term "Open Educational Resources" and recommended the following definition: "the open provision of educational resources, enabled by information and communication technologies, for consultation, use and adaptation by a community of users for non-commercial purposes" [18]. In this context, Open Educational Resources (OER) should refer "teaching, learning and research materials in any medium, digital or otherwise, that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions. Open licensing is built within the existing framework of intellectual property rights as defined by relevant international conventions and respects the authorship of the work".

The degree to which a resource is shared varies and an open resource depends which open license is in effect. In this regard [20] proposed that open content such as OER should allow the 5 R's of openness (originally 4 R's): Reuse, Revise, Remix, Redistribute and Retain. The idea of 5R's reflects concern with the intellectual property and authorship, and therefore in licensing resources and granting of non-restrictive permissions. The Creative Commons licenses indicate how the original authors wish users to modify and share any new derivatives of their work.

Sharing educational materials such as OER, under a CC license, allows adaptations in the content to better fit the needs of the community, considering the diversity of the students, the different cultural and social contexts and even the language. With OER the didactic content can be updated more effectively, following the pace of changes inherent to some disciplines due to the emergence of new discoveries [21]. These updates do not necessarily need to be carried out by the original author, highlighting the collaborative work. The ability to distribute derivative versions of a resource helps keep course content current.

The openness characteristic of these resources guarantees access to knowledge for all, regardless of social class, contrasting with the high cost of printed textbooks giving full support to learning. In addition, it creates opportunities for students to contribute knowledge and build their own learning paths [22]. These open pedagogical practices expand collaborative, inclusive, accessible and active learning. In addition to disseminating knowledge, strengthening communities and promoting innovative pedagogies.

2.3 Accessibility Issues

Understanding the accessibility theme, as a right for all, reinforces its importance for the inclusion process, especially for people with disabilities. However, this understanding is not yet enough to guarantee the necessary specifications that allow access to digital space for all citizens, regardless of their diversity of perceptual, motor or cognitive conditions, for example [23]. In this sense, the SELI contemplates in its proposal the challenge of providing all users of its ecosystem with the accessibility necessary for the proposed learning to take place autonomously, respecting the diversity of each user and guaranteeing access to all available information content. In order to access to be guaranteed, it is necessary to take into account the offer of assistive technology and the available accessibility resources [24].

The project followed the concept of accessibility proposed by the Universal Design for Learning (UDL). The UDL proposal is anchored in architecture focused on human diversity. The construction of the ecosystem considered in the teaching-learning process respect for the specific need of everyone, favoring the acquisition of knowledge with autonomy, independence and consistency [25]. Among the implemented accessibility elements can be mentioned: recommendation to use simple and clear language, use of each element for its purpose (title to title styles, table for tabular data, for example), use of standardized and known icons internationally and the use of colors with a good contrast ratio. Description offer for images that transmit content, means that facilitate navigation through the keyboard, cleaner fonts (letters), better understanding, alternatives for audio and video (subtitles, textual transcription, sign language), always available to pause audio and video with automatic start, avoid time-limited activities.

The entire process was guided by the importance of accessibility in the digital space considering the recommended technical standards and especially the user experience, the context and the conditions of the people who will use the tool because only then is it believed that it will meet the specificities of each user and could be considered accessible [26].

3 Digital Ecosystems for Learning and Inclusion: Related Work

Several initiatives have been found in the literature on the use of technology to promote inclusion, whether for people with disabilities [27–30], immigrants [31, 32], elderly people and other groups that face barriers or some situation of vulnerability regarding access to digital technologies [33, 34].

However, there seems to be a gap in the availability of platforms and ecosystems that promote learning and inclusion. The use of the term "platforms-forms" and "ecosystems" here refers to a set of services made available to educators and students, in order to allow democratization and the inclusion of learning, using, for this purpose, an infrastructure of support, philosophical and conceptual foundations.

[35] propose a metamodel for the definition and development of learning ecosystems taking into account the context and the human factor as key elements, that is, the ecosystem must be in accordance with institutional policies, governmental and cultural organizations and also to the target audience.

[36] present the sMOOC, launched by the European project "E-learning, Communication, Open Data (ECO)", in the perspective of social inclusion. The project's main objective is to promote professional training for socially excluded people. A model was used, combining formal and non-formal learning activities and cooperation between participants, in order to generate a continuous flow of knowledge between platforms.

Also, worth noting is the LATin project (Latin American Open Textbook Initiative), which aims to minimize the problem of the high cost of textbooks for higher education in Latin America. Thus, this project aims to create a support architecture, methodologies and policies for the dissemination of open cooperative books, aimed at higher education [37].

This project differs from the others in the proposal to be an ecosystem that uses open educational resources aimed at supporting the teacher to create accessible digital teaching materials according to the type of target audience that the teacher wants to include in his courses. Thus, the ecosystem provides computational support for student accessibility and pedagogical support for teachers.

4 Smart Learning Ecosystem

SELI ecosystem provides a solution framework for the teaching-learning process in order to promote inclusive education. As shown in Fig. 1, it is divided into four views: philosophical foundations, supporting infrastructure, concept and service bus.

4.1 Philosophical Foundations

Shared Pedagogy

The SELI project is based on the idea of exchanging experiences. These experiences are in a different way the content of education, methodical solutions, proven algorithms of pedagogical activities. Pedagogy is learning about educational ideals [38]. One of the ideals is the issue related to the transfer of knowledge and skills. Each of the teams involved in the project is responsible for preparing one or two courses dedicated to future teachers or current educators. The courses contain tested content, verified in terms of usability. The content is selected in a way that ensures the transfer of knowledge, skills and attitudes between the countries involved in the project. The courses are selected and designed to convey what is most valuable in a given country.

The selection of contractors for the action included several important keys, among others: topicality of the subject matter, reported needs of the platform's recipients (key and current challenges), as well as designing activities aimed at pedagogical practice (social change) [39]. In this case, it should be stressed that the idea of knowledge sharing lies at the heart of research and scientific activities. Pedagogy is a specific discipline that aims to strengthen competences [40]. This development is possible thanks to the idea of common learning regardless of cultural or language differences. Therefore, all content included in the ecosystem is created in two language versions (the original one is addressed to the local audience) and English. The application of the strategy of using two languages results from the simple fact of making the content more accessible to end users. Moreover, in many cases the design of content in the local language is due to the competence constraints of students and teachers (level of English use). Courses designed within the SELI framework concern, among others: the use of the ecosystem to work with migrants, disabled, digitally excluded [41], having problems with cyberbullying [42] or bilingual people. All courses will be available in one place - the SELI ecosystem. Each course will be the responsibility of a different country involved in the project. The idea of sharing the best educational solutions has a real stamp in this case.

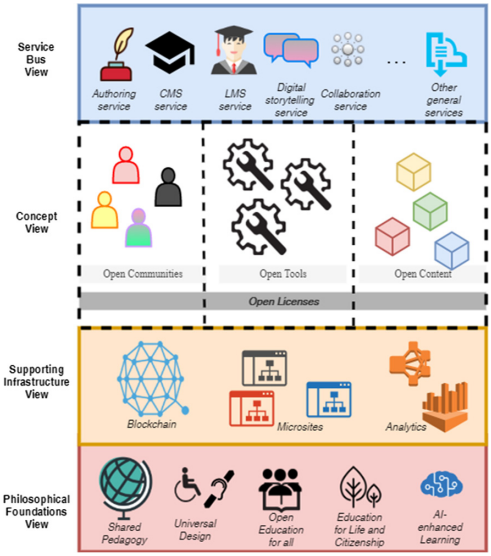

Fig. 1. Architecture of the smart learning ecosystem [43].

Universal Design. Designing an educational platform requires taking into account the needs of end users. Firstly, such a platform must meet the criterion of language accessibility [44]. Therefore, all content on the platform is bilingual, i.e. in the national language and English. The switchover to the language is automatic due to the location of the ISP. The second and very important issue is the design of a clear menu to allow

for familiarization with the content and the creation of educational content [45]. The platform therefore has a clear menu, which is adapted to a diverse audience. This means that both a person with a low level of digital competence and a high level of competence can effectively operate the platform [46]. Each of the graphic content is properly described for the speech synthesizer (the needs of blind people). Content layout planning has been tested and evaluated in different groups. The work on designing the platform taking full account of the needs of all its users is not an easy task also due to the high level of organizational and cultural diversity of the teams. In addition, the platform's assumptions require extensive testing in each country, which prevents short project duration. Nevertheless, every effort has been made at the conceptual, execution and implementation stages in terms of testing, error detection and correction.

Open Education for All. The issue of openness of resources is one of the main objectives of the SELI ecosystem. This assumption is based on several facts. Firstly, the ecosystem is built from public sources. Financing of the activity by national research agencies requires ensuring access for all citizens. Secondly, the effort put into preparing the learning environment requires the widest possible dissemination of the results. The functioning of the ecosystem is therefore open to everyone without territorial or linguistic restrictions (use of universal English). The third reason is to implement the idea of creating social change through ICT [47]. The teams participating in SELI hope that the use of the courses will contribute to solving selected problems in individual countries, e.g. relating to counteracting cyber-bullying, digital inclusion, working with elderly people using ICT, immigrants, or educational work with bilingual children. Each topic is prepared in a way that is accessible not only to professionals, but also to parents and learning communities (e.g. academia). It is assumed that open education does not require formal exams or admission requirements, but is based on the accumulation of human capital, whose repository becomes an efficient ICT tool [48]. It is also worth adding that all courses and architecture have been prepared in accordance with trends - styles of ICT use [49]. Thus, all open resources do not require special access devices [50]. They can be run not only on computers, but also on smartphones. Openness lies at the heart of the SELI project, setting out detailed directions.

Education for Life and Citizenship. Each of the prepared courses is characterized by some universal features, despite thematic differences. One of the main goals of education is to improve the quality of life [51]. This idea is the basis of the SELI ecosystem. Each course is oriented towards two groups: the target group (with deficits, problems, challenges) and the intermediate group (teachers, trainers, students, parents). The learning of the courses enables the generation of change, which is ultimately to translate into a better quality of life for disadvantaged groups. The content designed within the SELI ecosystem is designed for the acquisition of new competences by both the target and intermediate groups. The topics selected for implementation do not belong to the group of basic research, but are very close to social needs, deficits in society. Participation of each group, learning, improving quality of life is also one of the determinants of social integration and full inclusion. The choice of topics is not accidental, as it is oriented towards groups requiring social and educational support. The SELI ecosystem becomes a unique and important tool not only providing

integrated knowledge in several areas, but also showing fragments of social reality and groups requiring educational and social support.

AI-Enhanced Learning. AI-enhanced Learning aspects of this paper are related to the Learning Analytics infrastructure [52]. All information about students' interaction with course content is stored and new predictive models of students' success are built over these pieces of information. This is done using Machine Learning techniques, which involve different techniques, which vary from simple Supervised Learning methods (as Neural Networks, for instance) to more up-to-date techniques, like Explainable AI (XAI) [53]. By using this, the appearance of correlations between different habits of use (e.g. best time to perform a lesson, or the importance of finishing an optional activity in the final grade) and course contents, tasks and overall organization can emerge. In this context, Learning Analytics refer to storing and retrieving behavioral data collected from users while interacting with course contents or tasks to better understand a wide variety of aspects related to students' learning processes. In the context of this paper, the SELI ecosystem records a reduced, but sufficient set of users' data, like: time and address of login; activities clicked, selected and completed; number of dropouts; access control to static content; and other data stored on logs and the ecosystem's database. The main goal of applying Learning Analytics strategies over these pieces of information is to provide different reports with valuable information for teachers, students and other educational agents. A long-term goal for this ecosystem is to provide predictive analysis to support students with learning difficulties.

4.2 Infrastructure View

Key concepts about the supporting infrastructure of the environment include Blockchain, Microsites, and Analytics.

- **Blockchain**. According the EU report 2018, about blockchain in education defined key characteristics about this technology. These characteristics are, namely: (a) the end of paper-based system for certificates (Trust and Immutability), (b) automatically verify the validity of certificates (Transparency & Provenance, Disintermediation), (c) users on control of their data (Self-sovereignty), and (d) blockchain-based cryptocurrencies in education business models, see [16]. In addition to these characteristics, blockchain implementations should also include: (i) open source software, (ii) open standards for data, and (iii) implementing self-sovereign data management solutions. However, most solutions applied in education do not fulfil all these criteria.

  The decentralized and distributed nature of blockchain, as well as, the ability to run smart contracts, make the implementation of this technology interesting for the SELI project because it aligns well with the objectives of the project and its way to smarter interactions.

  The adoption of free and open source code, it has been a key mechanism to share details about the implementation of our system between all partners. After finishing a course, certificates are generated and stored as Smart contracts and non-monetary transactions on a private Blockchain network (ethereum.org). Students can access their milestones through the navigation menu, like Fig. 2.



Fig. 2. Front-end for presentation of student's certificates

- **Microsites**. There exist numerous tools available for generating class materials (e.g. EXeLearning). Nevertheless, one of the identified problems with these tools is related to encapsulation and recording internal state of used objects. Take as example a lesson including many webpages generated with EXelerning (packaged with SCORM), even if an internal questionnaire is answered by a student, no internal state is recorded. To address this problem of not recording some data, SELI ecosystem uses H5P objects because they can store more data about inputs from the end-user. The main challenge is to create and implement a flexible architecture to accept different types of objects from author tools and provide them with additional data gathering. H5P objects make functionality portable through the use of JavaScript language and objects. For this reason, the selected framework for developing the environment includes Node.JS + React + Meteor 4, and new non-relational databases like mongoDB.
- **Analytics**. Learning analytics refer to storing behavioral data from users to better understand how students interact with materials generated by the instructor. These data are not different from the information recorded by social media ecosystems. SELI environment records: time and address of login, activities clicked and selected, number of dropouts, and other data stored on logs and the database. The main goal is to generate different reports with valuable information for the teacher and students. A long-term goal is to provide predictive analysis to reinforce students with problems.

4.3 Concept View

Open Communities. They refer to the communities of practice, including all actors and stakeholders that will take part of any SELI-enabled educational processes. Roles must be considered instead of personified entities, so that besides teachers and students, a wide variety of roles could take part of these communities, from media and content creators to academic staff, being them or not active users of the digital platforms and tools provided by SELI ecosystem.

Open Tools. SELI ecosystem is designed over a mashup of open digital tools, and its architecture is open enough to any open digital solution to be added and integrated with the already existent ones. The first open tools already implemented inside the ecosystem comprise: a course authoring tool, a course management tool and a digital storytelling tool. Given the open nature of SELI, external open tools like those one provided by other open ecosystem could be easily incorporated by SELI. For instance, from LATIn Ecosystem [37], an open social network tool, a collaborative writing tool and a publishing tool are meant to be aggregated to SELI project.

Open Content. All content created inside SELI Ecosystem is meant to be freely and openly available, under a Creative Commons-like license. In the same way, any other kind of open content made available outside SELI platform can be incorporated by it, following the 5R freedoms. In this way, any external open content could be accommodated by SELI Ecosystem's own open repository.

4.4 Services Bus View

Authoring Service. The purpose of the authoring service is to offer the teacher digital resources that can support the creation of media for the construction of digital didactic material, as well as to support the adaptation of this material to include accessibility to didactic material. An example of creating didactic material for the ecosystem is shown in Fig. 3. In this figure, the teacher can insert different media, such as text, images, links, videos, audios, created by him/her or downloaded from the Internet with open access, for example, as well as a screen specifying a media type (Fig. 4). It allows teachers to create lesson strategies that can be used according to specific declines of students with disabilities, for example. media can meet the accessibility criteria established by the literature and the W3C [54]. Thus, they can insert aspects of accessibility, such as: descriptive text, audio description, sign language, etc. to improve the inclusion of digitally disadvantaged groups. In addition to the media, the teacher can choose activities that the student must deliver, such as tasks and storytelling, in order to verify the skills acquired by the students.

CMS and LMS Services. After the teacher publishes his courses, the CMS service is responsible for making them available to students. In the CMS the student can choose between courses of different levels of learning, in different languages. Then, the course can be saved and published on the ecosystem for student access, which is done through microsites that are linked to the CMS.

The microsite is a web page that will present the course proposed by the teacher with all the didactic content, regardless of the creation tool. This course can be run on different platforms on different devices. An example of published courses is shown in Fig. 5.

In addition to offering courses through the CMS service, the LMS service allows the offer of various types of activities, such as questionnaires and storytelling. It is also possible for the teacher to configure the evaluation criteria for each activity, in addition to monitoring the student's performance through the learning analysis component.

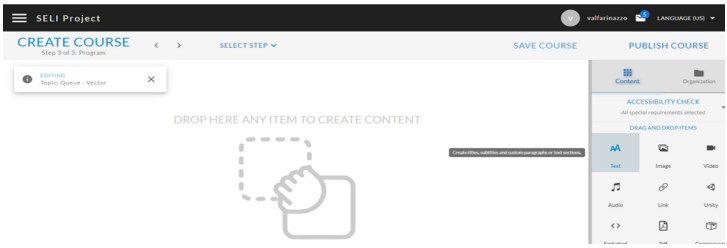

Fig. 3. Initial screen to create a course

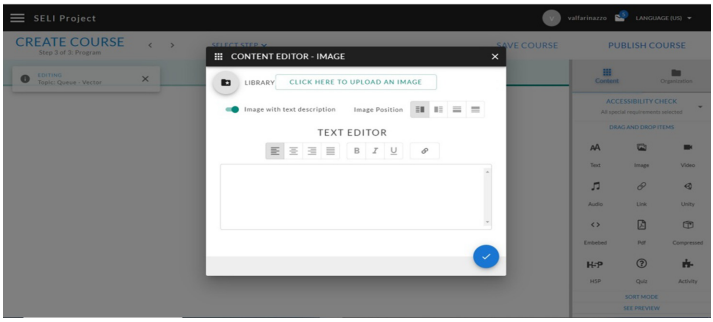

Fig. 4. Image settings

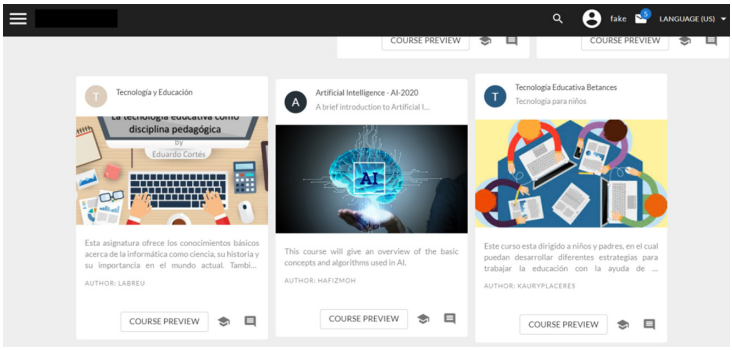

Fig. 5. Published courses

Collaboration Service. These services refer to the possibilities of collaboration among actors that are facilitated by SELI Ecosystem through its tools. They could be exemplified by the internal open tools, as the collaborative construction of digital stories, or even external open tools, like LATIn's collaborative writing tool.

Digital Storytelling Service. Digital storytelling is the art of telling stories or narratives by using any multimedia mean whether it is graphics, a program or a presentation. The ecosystem presents this service, according to Fig. 6. The story flow allows user to upload multimedia such as image, video, audio, text in one screen. It also allows user to translate text into five different languages (English, Polish, Portuguese, Spanish, Turkish) which is available as subtitle when shared in a learning activity or social media.

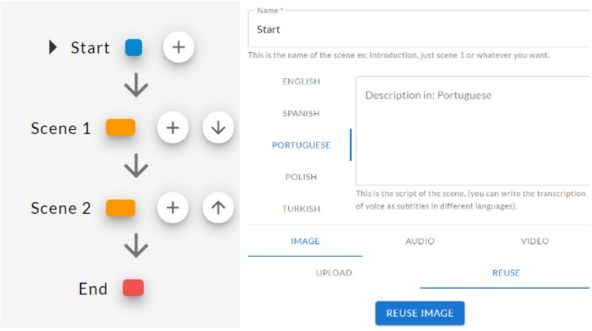

Fig. 6. Storytelling board view.

5 Conclusions

This paper presented the architecture of a smart ecosystem for learning and inclusion that is being developed by a group of 10 countries from Europe and Latin America. The details of the four views that make up architecture were presented: philosophical foundations, support infrastructure, concept and service bus.

This ecosystem aims to allow teachers to create their courses (content and activities) more easily and may include accessibility resources. Students, with or without disabilities, can access these materials available on a web platform. Thus, the objective of increasing the democratization of access to education can be achieved.

The ecosystem has been being tested since November 2019 in three different countries (Brazil, Dominican Republic and Uruguay). Teachers from public and private schools, accessibility specialists are using the authoring tool to build their courses. The data collected is being used to make improvements to the ecosystem by the development team in conjunction with the usability and accessibility team.

Further work includes collecting users' opinions about the ecosystem and analyzing users' data and start to use with students (with or without disabilities).

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