X5GON

X Modal
X Cultural
X Lingual
X Domain
X Site
Global OER Network

Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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ABBREVIATIONS

Acronyms	Definitions
OER	Open Educational Resource
API	Application Programming Interface
URL	Uniform Resource Location

ABSTRACT

In this report we present the final set of products and services developed in the X5GON project. Each service and product are found in its own section containing its description, functionalities and user interface, if applicable.

1. INTRODUCTION

The purpose of this document is to report on the final set of the products and services developed in the X5GON project. The objective of the project is to create a cross-modal, cross-cultural, cross-lingual, cross-domain, and cross-site global OER network. In order to do so, we developed a number of services and products that would help us achieve this goal. Each service has its own section describing their functionalities and visual design (if applicable). All services are publicly available and their code is open source on Github[1].

The document is structured as follows. Section **Error! Reference source not found.** focuses on the X5GON Platform, the service that indexes, processes, enriches, translates and stores the OER metadata and make them available via the public API. Section **Error! Reference source not found.** focuses on the X5GON Connect Service, the library that connects the OER providers to the X5GON Network. While Section **Error! Reference source not found.** presents the X5GON Search Engine, the X5GON Discovery tool is described in Section 5. Section 6 focuses on the Recommender Engines that provides personalized recommendations. Section 7 gives an overview of the Learning Analytics Machine, and Section 8 describes the Moodle plugin called X5-Moodle. X5GON Blind, the learning environment tailored for the blind and visually impaired, is described in Section 9. Finally, the X5Learn learning environment is described in Section 10. We conclude the document in Section 11.

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[1] https://github.com/X5GON

2. X5GON PLATFORM

The X5GON Platform is the products that collects, processes, enriches, translates and stores the OER metadata found across the globe. It also serves as the entry point to various services and products, as well as provide information on the products, transparency and privacy policy adopted within the project. The platform is publicly available at https://platform.x5gon.org/.

Since the X5GON Platform was already presented in D2.3 – Visual Interface, we provide a brief overview of the product and report on the updates.

The user interface of the X5GON Platform is designed to provide as much information in the simplest way. It describes both the motivation for developing the X5GON services and products, as well as who can benefit from them:

- **Learners:** Learners will be provided with the ability to learn, discover, compile playlists and make notes to solve problems, and enhance their learning pathways with the recommended items.

- **Teachers:** Teachers will be able to access OER material quickly and across multiple subjects. The platform allows them to design, browse, discover, collaborate on and publish your own materials.

- **Researchers:** X5GON allows access to OER data for the world of data science and research to create more value via reuse and repurpose of data. We have a suite of data streams to bring OER content and features to your hackathon, repository, institution, website and apps. We make it easy to work with the X5GON API and even integrate to grow your project, business or repository around OER content. On top of these, all the codes of services developed during the project are openly available on GitHub.

- **Institutions:** Our ecosystem can be used as an infrastructure that transforms quality, institutional level structured and unstructured content into a dynamically evolving knowledge graph that quantifies complex relationships between content and users or learners via the enrichment of concepts in multiple languages, modalities and formats.

- **Governments:** X5GON thrives on interconnecting national repositories, uncovering and enriching content and discovering unexpected relationships. We are developing the most accessible, comprehensive platform for government funded OER in order to support the next generation of global digital education equity. In particular, the catastrophic COVID-19 pandemic experience proved once again there is a huge gap between the countries in readiness of technology and digital pedagogies[2]. There is a need for OERs and digital education more than ever. With open and machine learning supported ecosystem, we believe X5GON is a great opportunity for governments.

The website also has a "call to action" for the OER providers to join the Global OER Network and to feely use the services and products available by the X5GON project. The services are accessible through a public API[3] and is well documented – each API

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[2] https://en.unesco.org/news/startling-digital-divides-distance-learning-emerge
[3] https://platform.x5gon.org/products/feed

route is described by its query string parameters and its response body attributes. An example of the documentation is shown in Figure 1.

Available methods

GET	/search	Get a list of relevant open educational resources

**Search for relevant materials**

GET	/search

Get a list of relevant open educational resources.

Query string parameters

text	Type: String	Title: Query Text	Optional: false	The seed text from which the system finds the relevant open educational resources.
types	Type: String	Title: Material Types	Optional: true	The type of open educational resources. There are two approaches of setting this value: (1) set the type group. Options: all, video, audio, text, and image. **Note:** When all, it will retrieve only video, audio and text materials. When the type is image, we use the Creative Commons Search API to retrieve the images. (2) provide a string of file extensions separated by a comma (example: `pdf`,`doc`,`docx`,`mp4`). **Default value** is **all**.

Figure 1. An example of the X5GON API documentation. The example shows the upper part of the search API route used to search through the OERs in the X5GON database.

The OER processing pipelines have been modified to also support processing text scan files. We developed an optical character recognition (OCR) component that can extract text from images. The component has been added to the text processing pipeline in the content extraction step. Figure 2 shows the final OER processing pipeline schemas.
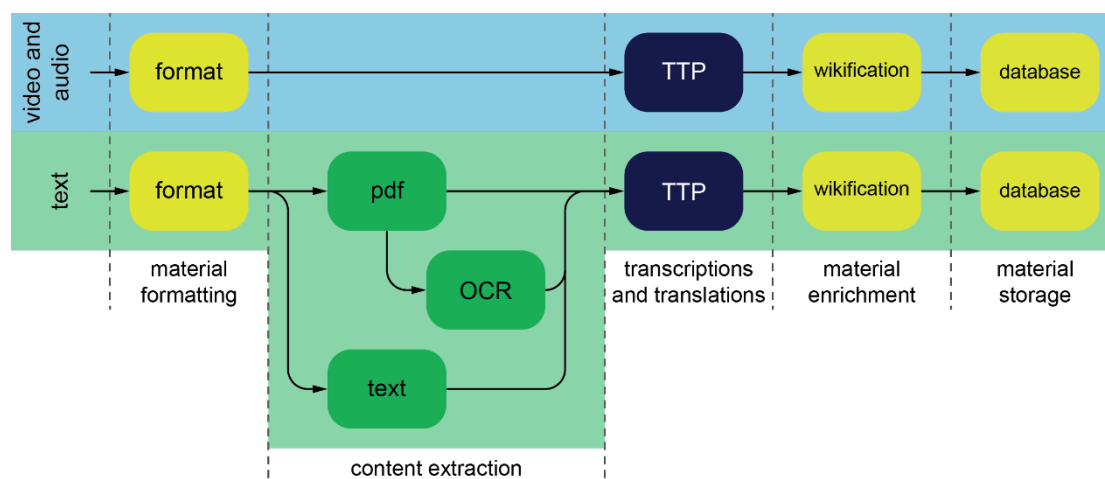
Figure 2. The OER processing pipeline schema. The blue schema shows how video and audio OERs are processed, while the green shows the pipeline for the text OERs.

The TTP in the schema represent the Transcription and Translation Platform (TTP). With it we are able to translate textual documents as well as get transcriptions and

translations from video and audio files. While TTP models are described in deliverable D5.3 – Final report on piloting, the OER processing pipeline descriptions can be found in D2.2 – Final server side platform.

3. X5GON CONNECT SERVICE

The X5GON Connect Service is a library that allows the X5GON Platform recognize which websites containing OERs are being accessed. The library is developed to be integrated on the OER repository (on the sites that include OERs). Then when the user visits the site (and gives consent), the library sends anonymized information to the X5GON Platform. The anonymization is performed to follow the GDPR regulations.

The data that the library sends includes: 1) the user ID which is randomly generated without using he users personal information, 2) the URL of the visited site, 3) the time and date of the visit, 4) the referrer URL (from website from which the user came), and 5) the user agents (the technology that the user used to access the site).

The acquired data is then used for user modelling in the X5GON Recommender Engine (see Section 6). More details on the X5GON Connect Service and how it is used can be found in D4.2 – Final prototype of user modelling architecture.

4. X5GON SEARCH ENGINE

The X5GON Search Engine allows the user to search through the OERs that have been processed, enriched, translated, and indexed in the X5GON database. Since its implementation and description was already described in the deliverables D4.3 – Final prototype of recommendation engine, and D4.6 – Final prototype of cross-language recommendation engine, we provide a brief overview of its functionalities.

There are two versions of the search engine both available via the X5GON Platform:

The first version of the search engine used the "content-based recommendation" method as described in deliverable D4.3 – Final prototype of recommendation engine. This approach represents each OER material as a collection of its relevant Wikipedia concepts retrieved in the material enrichment step of the processing pipeline (see Section 2). With this approach we are able to compare OERs in different languages.

The second version integrates the Elasticsearch (ES)[4], a distributed, RESTful search and analytics engine. With ES we index the OER metadata and developed a microservice that is able to process the user requests, transformed it so that ES is able to process it, formatted the OERs and returned the found results. The user query can contain various parameters, such as the text, the types, licenses and languages of the OERs, and other. This version is also able to provide cross-lingual results, but has a bias towards OERs that are in the same language as the query text – but that can be regulated by providing the appropriate language filters.

Both search engines are accessible via the X5GON Platform API[5] and are documented.

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[4] https://www.elastic.co/elasticsearch/
[5] https://platform.x5gon.org/products/feed

5. X5GON DISCOVERY

The X5GON Discovery is a search service where one can find OERs by sending requests to the X5GON Search Engine (see Section 0). The Discovery was developed to easily search through the OERs, allowing the student or teacher find the resources that would help in their learning process. The Discovery uses the second version of the search engine for searching through the OERs. It was design to be viewed on the computer screen, tablet and mobile phone and is publicly available at https://discovery.x5gon.org/.

Since its description and functionalities of the X5GON Discovery were already presented in deliverable D2.3 – Visual Interface, we provide a short overview of its design and functionality, as well as the improvements performed since its last reporting.
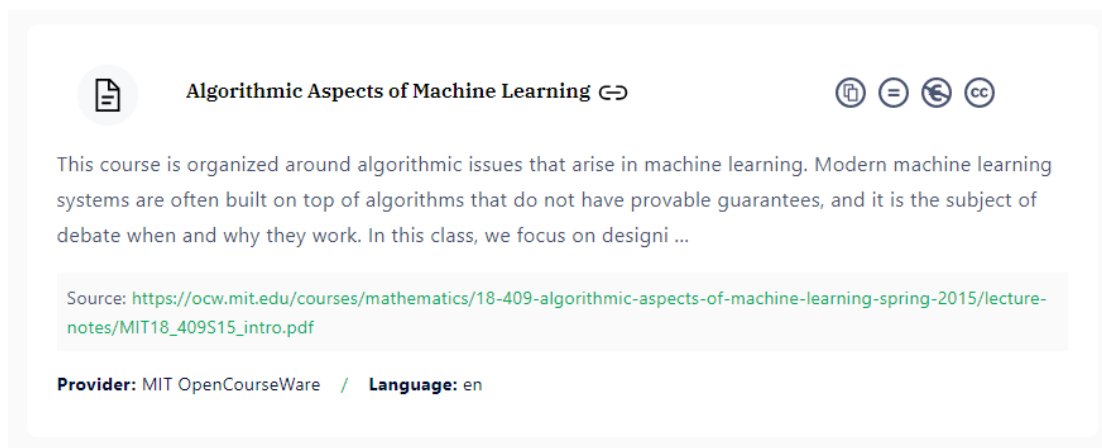

Figure 3. The X5GON Discovery home page. It contains a search bar and suggested queries for the user.

Figure 3 shows the X5GON Discovery home page. It has a simple design with an input bar and suggested queries which the user can use to search through the relevant OERs. These OERs are shown in list and are presented with the following information:

- **Title.** The title of the OER material.
- **Description.** The description of the OER material.
- **Type.** The type of the OER material. There are four options: video, audio, text and image.
- **License.** The license of the OER material. The materials that are under one of the creative commons licenses[6] have a visualization corresponding to the license.
- **Source.** The URL to the actual OER material.
- **Website.** The URL to the website that provides the OER material.
- **Provider.** The provider of the OER material.
- **Language.** The language of the OER material.

An example of the OER representation in the list is shown in Figure 4.

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[6] https://creativecommons.org/licenses/
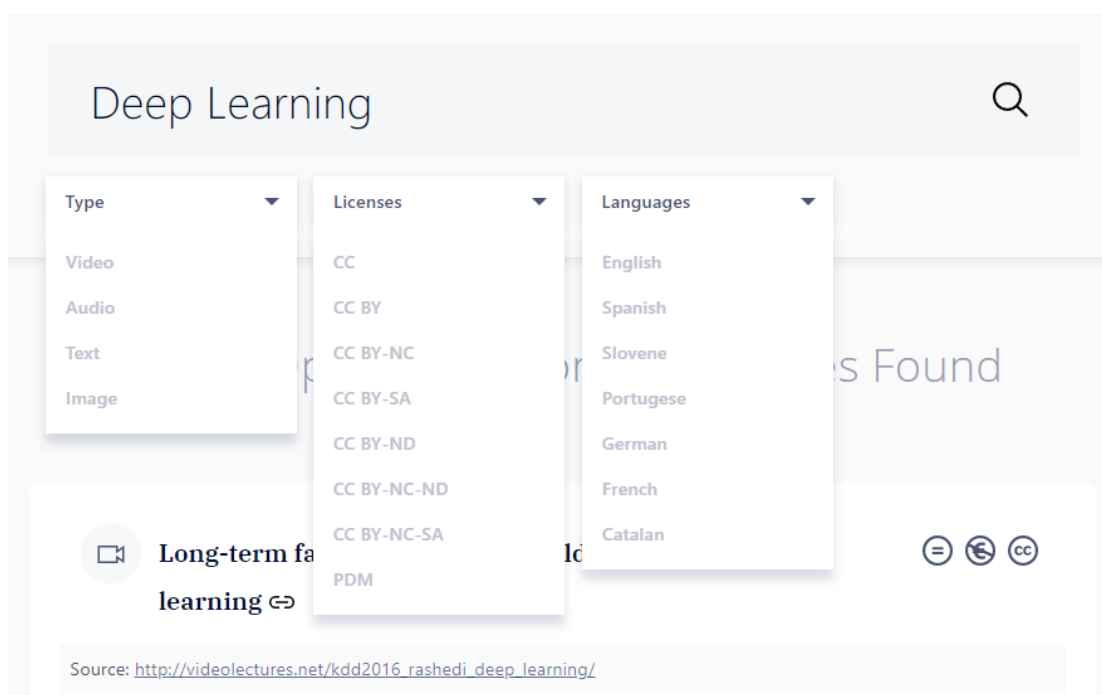
Figure 4. The X5GON Discovery material example for the search term "Machine Learning". It shows the main information of the OER material.

In addition to searching through the OERs, we have also implemented filtering options. One can filter the search results by specifying the following material attributes: **type** (video, audio, text, and image), **license**, and **language**. The user can select multiple filtering options at once. Figure 5 shows the filtering options and their location.

Figure 5. The search filter options. The user can filter through the material type, license, and language.

At the top of the visual interface we also added the "Our Databases" tab which navigates the user to the X5GON database statistics. The statistics include the number of OERs in the database, the number of user activities performed on the OER providers that are connected to the X5GON Network and the specific number of OERs and visits per connected OER provider.

6. X5GON RECOMMENDER ENGINE

The X5GON Recommender Engine is a service that provides meaningful OER recommendations based on the users interests. The three recommendation approaches that are implemented and available are 1) the content-based recommendations, 2) the OER bundle-based recommendations, and 3) the collaborative filtering approach. The methods are presented in the deliverables D4.2 – Final prototype of user modelling architecture, D4.4 – Final prototype of recommendation engine, and D4.6 – Final prototype of cross-lingual recommendation engine.

The service is publicly available via the X5GON Platform API[7]. To retrieve the recommendations, one must send a query containing either the text (similar as with the X5GON Search Engine) or the URL of the website that contains the OERs already indexed in the X5GON database.

The results of the X5GON Recommender Engine can be integrated in an arbitrary website using the X5GON Recommendation Plugin. The plugin can be embedded in the website by using the HTML iframe tag. Figure 6 shows the recommended OER list generated by the plugin.
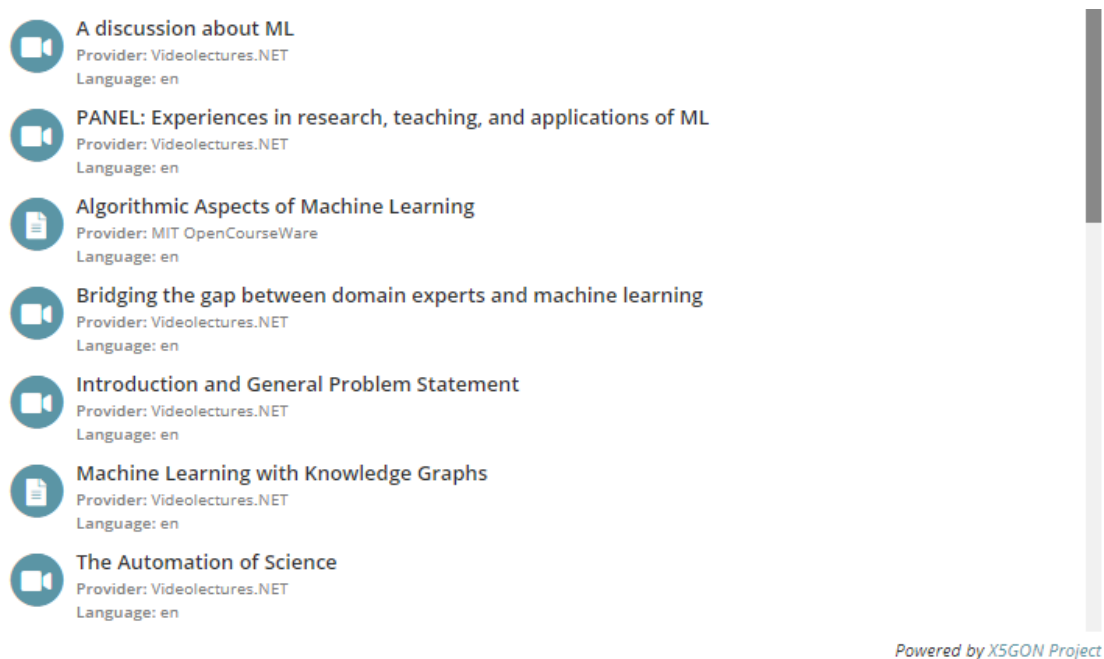
Figure 6. The embedded recommendations using the X5GON Recommendation Plugin for the text "machine learning".

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[7] https://platform.x5gon.org/products/feed#version-1-recommender-rest-api

7. LEARNING ANALYTICS MACHINE

The Learning Analytics Machine (LAM) was built as a connecting component of the models and heuristics computed within WP3 – Learning Analytics. With the goal of using the developed models and heuristics as metrics for the global X5GON recommendation system and other applications, the LAM is based on several exciting research ideas, focusing on the learning aspects and how to use the indexed OERs. These research ideas and approaches include: 1) a variety of OER representations (based on keywords, concepts, doc2vec, etc.), 2) learning the difficulty of the OERs, 3) computing the coherent order of the OERs in the observed subset, 4) predicting the missing resource between two distant OERs, and other.

The final format of the LAM is a publicly available REST API. Following the REST style design, the microservices architecture and implementing many performance optimization mechanisms, the LAM API is able to handle any potential technical needs, such as large-scale traffic or huge outputs sizes. The LAM API is able to handle any requests associated with the current X5GON specifications, e.g. up to 120k OERs with about 30M of OER-user interactions). The services are often dealing with large sizes of data (for more details, please refer to Section 2 of D3.3 – Learning analytics engine 3.0).

The LAM API is intended to be used by a large specter of groups outside the X5GON consortium, which include researchers, developers, and events. As an example, the LAM API was a key technical infrastructure used during the F'AI'R hackathon in Paris[8].

As a second example of its exploitation, we developed a dashboard that makes use of the many service API endpoints to illustrate the following learning scenario: building a coherent playlist from a set of OERs. The dashboard is publicly available at wp3.x5gon.org.

The LAM API will be used mainly for its independent functionalities through the different endpoints. An alternative way to test and use the endpoints is through the interactive documentation available at wp3.x5gon.org/lamapidoc.

The documentation provides all of the required information to start using the available services, including the description of the service, the input parameters and the output fields. The API is easy to use and test, to manipulate the results in real-time and access its related specification using this simple web interface (see Figure 7 for an example).

Due to the diversity of the provided API endpoints and their corresponding specifications, we clustered the endpoints into several groups. Depending on the type of the output information, we created 10 different groups – each one containing one or more API endpoints. In summary, the groups can be classified into two categories:

- The ones dealing with the representations of the OER, e.g. processed content, TF-IDF weighting, wikifier, doc2vec based representations; and
- Those that deal with AI heuristics computed on the OERs, which include providing OER recommendations, sequencing OERs, measuring the difficulty of the resources, and other.

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[8] x5gon.org/event/ai-hackathon/

Figure 7. Example of the LAM models API documentation. The documentation contains the description of each model, how to use it, as well as the input parameters and the outputs format.

These two groups reflect our willingness to provide both essential natural language processing tools (such as tools for measuring the similarity/distance between the OERs, and preprocessing and preparing OER representations) and the cutting-edge tools specifically adapted for the learning aspects of the resources, e.g. the difficulty of the OERs and the sequence of the OERs, among others.

Up to 40 API endpoints are available in LAM distributed into 10 different groups, including temporal, sequencing, searchengine, recommendationsystem, and difficulty. An example of the difficulty API endpoint execution is shown in Figure 8.

Figure 8. The difficulty API endpoint execution example provided by the Learning Analytics Machine.

8. X5-MOODLE

The X5-Moodle is a Moodle activity plugin implemented based on 2 key ideas: 1) providing AI-based smart tools for delivering open resources as a support during the course session, and 2) evolving the tools through the usage-based approaches rather than focusing on the user data. The aim of the plugin is to provide the teachers and students the best learning experience.

Using the OER collection and the AI tools developed within X5GON, a new learning activity is designed following the Moodle specification and workflow, as well as the new-fashioned spirit of using AI to support learning. The X5-Moodle uses:

- The X5GON Search Engine (see Section 4) to find more OERs, and
- The X5-Recommend item-based system available via the Learning Analytics Machine (see Section 7) to provide recommended OERs based on the resources' usage history.

The plugin can be used through 2 different perspectives: the teacher and the students.

From **the teachers** point of view, the plugin is mainly a configuration interface in which they can choose between 3 functionalities that can be seen by the students: The X5GON Search Engine, the X5-Recommend, and the X5-Playlist provided by the X5Learn (see Section 10). The teacher sets up the required configuration of the specific functionality, such as the Search Engine initialization, playlist upload, and other. Figure 9 shows the Moodle interface where the teacher configures the plugin functionalities.
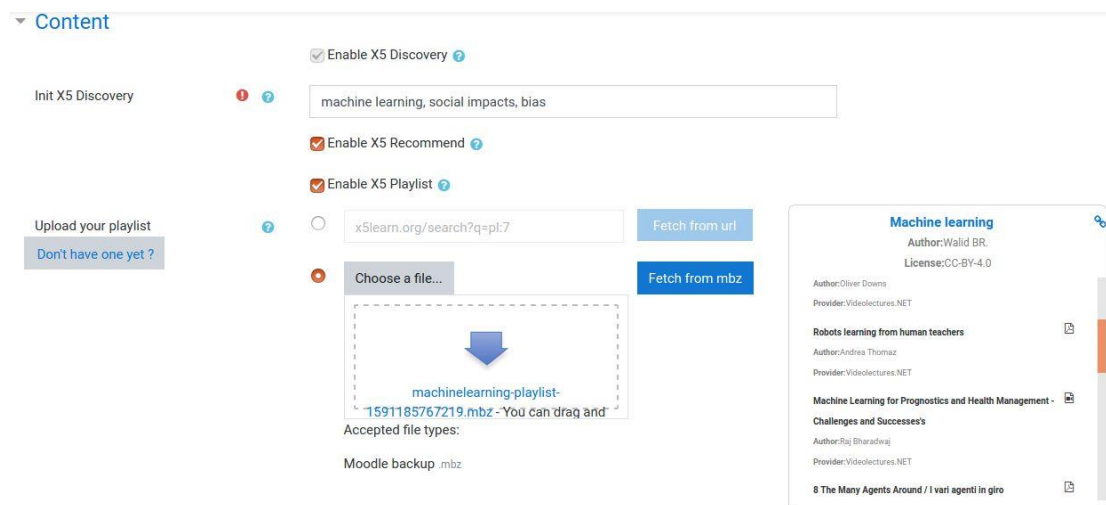
Figure 9. The Moodle plugin interface allowing a teacher to choose the X5GON activity, e.g. X5GON Search engine, the X5-Recommend and the X5-Playlist.

Once the plugin is instantiated inside the Moodle course, the **students** can see the plugin functionalities configured by the teacher. The X5GON Search Engine allows the students search for new OER resources. In addition, they are able to see a list of the most frequent search queries performed by the course participants. Figure 10 shows an example of the configured X5GON Search Engine view in the Moodle.
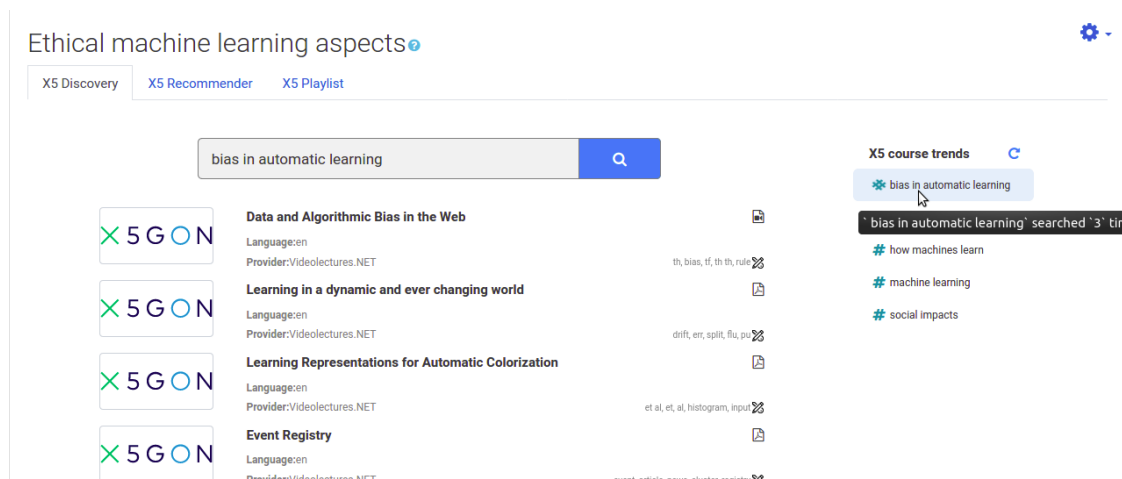
Figure 10. The X5GON Search Engine functionality in the X5-Moodle. With it, a student can search through OERs as well as see the most popular search queries.

The X5-Playlist functionality allows the teacher to embed a playlist that was created through the X5Learn service. The published playlists can be embedded into the Moodle course via the plugin, making it available to the students. Figure 11 shows the embedded playlist in the Moodle course.
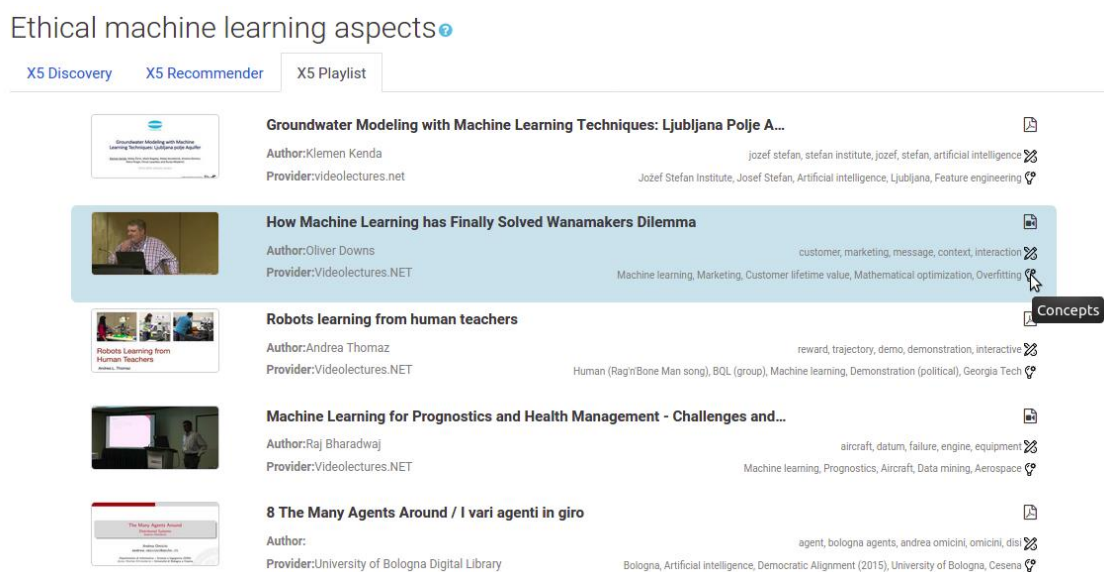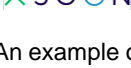

Figure 11. The X5-Playlist functionality embedded in the Moodle course. The example shows the teachers playlist created using the X5Learn service.

The X5-Recommend functionality provides OER recommendations based on the students current work. It also provides viewing statistics, e.g. how many times an OER was viewed by the students' fellows, as well as additional OER metadata. Figure 12 shows an example of the OER recommendation list.

Figure 12. An example of the integrated X5-Recommend list. It shows the recommended OER resources as well as the viewing statistics of the student and its fellows.

With the objective of improving the learning experience of both the teacher and students, the X5-Moodle is designed to offer several features that hopefully will lead us to achieving our objective. These features include:

- OER based search engine through the rich X5GON OER network.
- Usage-focused functionalities, instead of tracking the users.
- X5-Trends, the most popular search queries based on the viewers' history.
- Extra information about the OERs, including the history of views, the OER metadata, and the enriched information such as keywords, concepts, difficulty score, and other.
- X5-Recommend. Built as a linear combination of the recommendations from the item-based X5GON recommendation system and the popularity of the viewed OERs in the Moodle course. The recommendations are systematically evolving (with popular and new resources) with the students exploration as well as the Moodle class shifting their attention to new OERs.

9. X5GON BLIND

The X5GON Blind service is a prototype of a learning environment tailored for students with perception related disabilities, more specifically the blind and visually impaired. The development of the prototype included the creation of an intelligent recommendation model named **Pythia**, which was inspired by the TrueLearn algorithm [1] used in X5Learn (see Section 10). The service is available at https://blind.x5gon.org/.

Unlike other recommendation approaches that employ uninterpretable models, Pythia creates an understandable personalized model that tries to predict accessibility of the materials by modelling the users' accessibility preferences. The parameters that the model learns about the student are based on ISO accessibility standards, including the standards for the assistive technologies. The model works without any prior information about the student's disability and learns only from interaction with OERs.

Besides predicting and providing recommendations to the individual, Pythia offers additional information to the teacher working with students. Using the learned parameters, students are grouped corresponding to their actual preferences and accessibility styles. This information can help the teacher at making better preparations and work with his/her students, consequently offering more compelling classes.

The core functionality of Pythia is to filter out learning resources that are suitable (accessible) for a particular user. Learning resources are sorted into classrooms and can be catered to a wide variety of different accessibility groups. The teachers simply need to include the materials which cover the needs of the learning group. Afterwards, the recommendation algorithm filters the materials that are relevant for the students.

Students use the user interface that sends requests the recommendation engine. They first choose a classroom (or a teacher) that they want to attend. In order to protect the user information, the student can enroll only in classrooms that are maintained by their teacher. Classrooms are attended online and are created to be visually appealing for the students with perception related disabilities (see Figure 13).
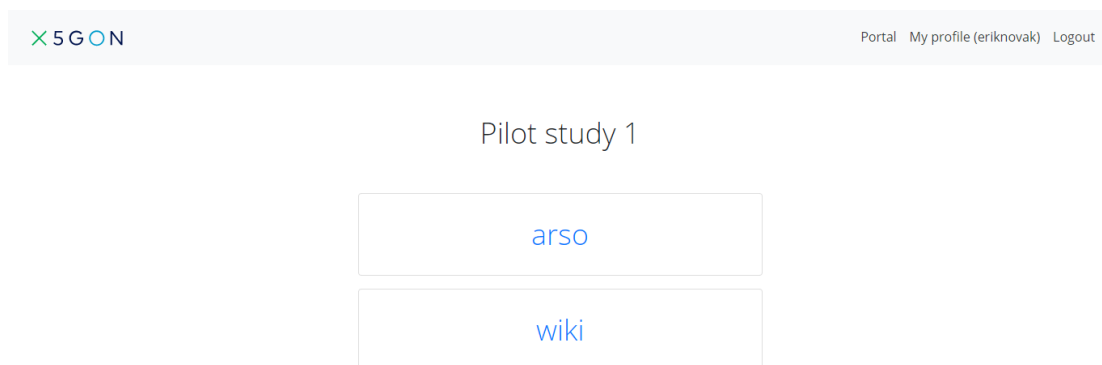
Figure 13. The X5GON Blind user interface. The design is tailored for the blind and visually impaired users.

When a student attends the classroom he or she has access to all of the materials prepared by the teacher. By attending the classroom, the student also agrees to share parameters learned by the system with the teacher. There, the student has access to all materials prepared by the teacher. These are arranged in a way that the most accessible materials appear closer to the top of the list.

10. X5LEARN

X5Learn is a product that provides users with a number of tools to access OERs. It is intended to support both teachers and students. For teachers, it provides a powerful platform to enable them to reuse, revise, remix, and redistribute courseware produced by others. These can be videos, pdfs, exercises and other online material. For students it provides them with a scaffolded and informative interface to select content to watch, read, make notes and write reviews. In a nutshell, X5Learn is a human-centered AI-powered recommendation engine for supporting online learning. It is available at https://x5learn.org/.

What makes it stand out from other MOOCS and OERs, is how it has combined human-centered design with ML algorithms and software tools with the goal of making it intuitive and easy to use, as well as making the AI transparent to the user. Much thought went into the design of the interface so as to give the user both a sense of control and choice. The AI was also designed to scaffold learning by providing structure and personalisation. It works both in the foreground and background; suggesting what videos the user might like to watch and in what sequence while enabling the user to take over at any point and choose for themselves. It works on two levels: First, it analyses specific features of the educational material, estimating the quality and difficulty of those materials. Second, it calculates and recommends a playlist of materials (e.g. videos) that it considers will match what the teacher thinks is best for the learner at that stage.
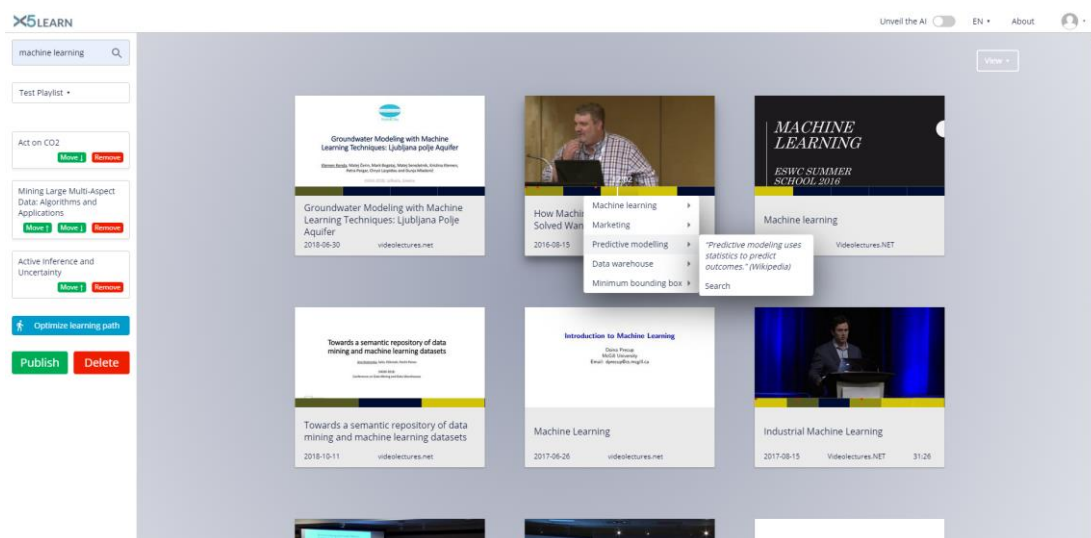
Figure 14. The video player GUI showing thumbnails of videos returned by the search engine, the playlist, the AI function for optimizing the learning path and the 'unveil the AI' function in the top righthand corner.

The GUI is designed based on a familiar digital video player metaphor (see Figure 14). It also integrates a number of well-known visual features, including a search box, popup boxes, cascading menus, timelines and visualisations. A novel function provided at the interface is the **Content Flow Bar**. After initiating a search, users can then view the results as video thumbnails in a window (showing title and date published). The challenge often facing a user is that there could be 10, 20 or even more videos returned by the X5GON Search Engine. How do they decide which to look at first? It can be very time consuming to find the required video content going through each one sequentially.

The Content Flow Bar works by providing semantic "snippets" related to the video content that pop up on the screen depicted in the form of a visualisation (see Figure 15).
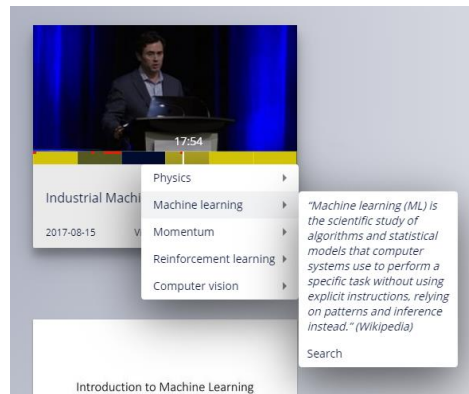
Figure 15. The content flow bar. The red lines on the yellow bar show the keyword 'machine learning' appearing and with Wikipedia definition that pops up using the cascading menu.

The tool enables the user to look rapidly through the content and in doing so be able to see at a glance what is covered in a particular video. As with other video tools (such as YouTube) the user can move their cursor along a timeline and stop it at any point to play from that point. Where it differs from other digital video players is it provides keywords that are being referred to in the video in the form of pop-ups. Moving the cursor from beginning to end will rapidly show what topics are covered at any given point. A further cascading menu shows the keyword in context as part of the sentence in which the keyword is embedded. These are extracted using Wikipedia tools. More contextual information is provided through swimlanes. In each swimlane, different keywords that appear in the video are represented on the timeline by a yellow or brown dot, where each dot is associated with a text snippet extracted from the video content at that time (see Figure 16).
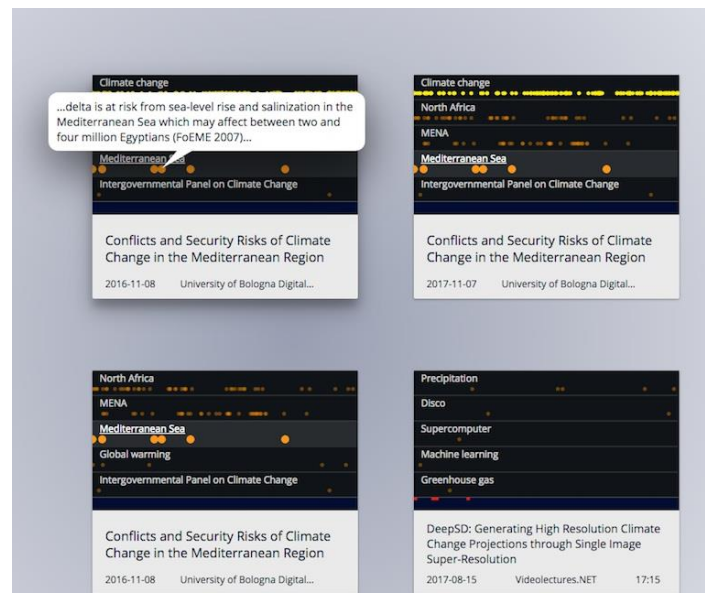
Figure 16. Swimlanes showing where and how often a keyword appears in the video with the sentence below the visualisation where they appear. Clicking on a dot brings up the sentence in which it occurs providing context.

The playlist also illustrates how the AI and HCI work together effectively: from an AI perspective we have provided an "optimise learning" function which automatically reorders the video sequences based on its assumed best learning sequence. From an HCI perspective, the tool enables the user to take over control and reorder the video sequence if they are not happy with what has been recommended by X5Learn. The ML will remember these and continue to use them in training the algorithms.

Other tools at the interface include a playlist feature, an annotation tool, a note taker and a place to write reviews. There is also a button that reveals how the AI works (see Figure 17).

Figure 17. The AI explain button.

A series of user studies of X5Learn has shown how this hybrid approach can support fluid interactions; teachers and students happily let the AI make recommendations but then like to take over to finalise the task; by using the novel content flow bar tool to see for themselves what topics are covered in a video.

11. CONCLUSION

In this document we listed the products and services that have been developed within the X5GON project:

- **X5GON Platform.** The product that indexes, processes, and stores the OER metadata, and makes them accessible via a public API.
- **X5GON Connect Service.** The library that connects the OER repositories to the X5GON Platform.
- **X5GON Search Engine.** The search engine for OERs in the X5GON database.
- **X5GON Discovery.** The product that allows the user to search through and filter the OERs in the X5GON database.
- **X5GON Recommender Engine.** The recommender engine used to provide OER recommendations to the user.
- **Learning Analytics Machine.** The product that provides different learning analytics tools to the user.
- **X5-Moodle.** A moodle plugin that provides X5GON functionalities to Moodle.
- **X5GON Blind.** The prototype learning environment tailored for the blind and visually impaired.
- **X5Learn.** A human-centered AI-powered recommendation engine for supporting online learning.

The services and products were evaluated and presented at various events. While they did provide positive responses from its users, there is still room for further development to make the learning experience of all even better.