Learning object repositories for novel, efficient knowledge creation and sharing

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2. ABSTRACT

Educational settings such as virtual campuses need efficient, user-friendly and seamless creation, search and consumption of open access and restricted access (internal) digital learning resources. Today's workflows are often lacking in these regards. Learning resources are created using standalone tools, published separately to internal and external knowledge stores and publication targets. Differing metadata schemes are often used, requiring manual entries of resource descriptions due to a lack of connectivity with study information systems (SIS) and other authoritative sources of metadata. Loss of productivity is an obvious disadvantage of this malpractice, because of manual re-entries, file copying and versioning woes across sources and destinations. In addition, stimuli for creating reusable learning resources are often sorely lacking. Difficulties in securing the integrity of learning resources and metadata when moving them from system to system poses additional challenges. The resulting cumbersome, inefficient, costly and non-intuitive production, storage and publishing of learning resources can hamper the educational process significantly.

The Norwegian University of Science and Technology (NTNU) and BIBSYS Library System (now a part of Unit[1]) has cooperated in bridging most of these issues in the DLR learning object repository (LOR) effort, taking care of both internal (LMS/assessment systems etc.) and open access publishing. High productivity and workflow features as well as support for stimulating the production and publication of learning resources is a part of the DLR package. The system has evolved from a simple tool with learning technology interoperability (LTI) support of LMSs (and other compatible application systems), into a high-productivity tool with support for open and restricted access resources. The Norwegian Business School (BI) and Oslo Metropolitan University (OsloMet) is joining in to develop this as a vital learning object platform (LOR). Several other institutions, such as the University of Bergen (UiB) are currently looking into the solution. The presentations of DLR in Eunis 2019 discuss some central challenges, use cases and features of some of the applications and adaptations of some of these institutions. DLR is gaining support from the Ministry of Education and Research (KD) as well.

In DLR a high productivity user interface experience is blending into the native application systems such as LMSs, ideally indistinguishable from the application systems themselves and with support for added functionality when applicable. Given appropriate support in application systems such as LMSs, all storing, searching and re-use operations should be directed to the DLR LOR in order to produce a

[1] Unit, the Norwegian Directorate for ICT and Joint Services in Higher Education and Research

optimal user experience (UX). Multi-author versioning (in a forking fashion) can be supported. Active resources (code checking, digital twins, simulators etc.) can also be added. Single click automatic open publishing is supported, with an expandable palette of preconfigured licenses present such as internal licenses, custom licenses and Creative Commons. DataCite Document Object Identifiers (DOIs) can be generated automatically if the desire to do so is expressed simply as a checkmark in the single page publication dialogue. Curation (or moderation) of the subsequent open access publishing of these learning resources can be defined, typically carried out by the library of the HEI. The publication function can optionally use open educational resources (OERs) hierarchies or similar open access systems, relieving publishers of manual operations, and gaining access to all resources there in return.

In addition to the advances discussed in user interface and functionality, organizational issues are important for the success or failure of LORs such as the DLR. There is a need for a steadfast commitment from boards and management. Traditional divisions between sections of university management, library, AV-section, IT department and educational support sections must be bridged. Stimuli such as meriting must be used to stimulate learning resource production and publishing.

Unit was assigned by The Ministry of Education and Research to investigate the possibilities and obstacles associated with increasing the sharing of learning resources across universities in Norway. While landing on DLR as the technical solution to solve the problem, the final investigation report states very clearly that the technical solution alone is not enough. To enable the sharing of digital learning resources, the report emphasizes a need to build a culture for sharing, through change management and built in incentives using meriting and funding. It is furthermore argued that learning objects should be regarded the same way as research data as belonging to the public, being created through public funding, thus introducing FAIR-principles[2] as key values for learning resources[3].

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[2] In research data management the principles Findable, Accessible, Interoperable and Reusable was coined in 2016 in a Scientific Data publication and has from there on set a common ground for the work with research data, https://www.go-fair.org/fair-principles/.

[3] Investigation of common national solutions for access to learning resources across educational institutions, Unit, May 2019.

3. INTRODUCTION

During the early evolution of electronic learning mainly in the 1980's through a very hectic period of the 1990's (Ross, 1999), electronic learning systems such as Learning Management Systems (LMSs) were aiming at satisfying the learning resource needs of those enrolled into a higher education institution. In the other end of the LMS spectrum, Massive Online Open Courses (MOOCs) were meant to offer digital learning resources to the open course market, gaining momentum in the 2010's (Zemsky, 2014). Today digital learning resources come in several shapes and forms, from the most complex such as entire courses, to the simplest such as illustrations and tables ("learning atoms", NS 4180:2017). In all cases, the actual learning resources were stored internally in the separate LMS and MOOC platforms, often in non-shared separate learning resources for each HEI. Manual operations were required to create, upload and describe those resources. Reusing those resources in other systems was more often than not a cumbersome process.

The problems were soon identified, and a new concept was born: Learning object repository (LOR). LORs were promising to offer better sharing of learning resources. Traditional LMSs able to share learning information across different organizations soon claimed to posess LOR functionality. This wave of sharing has recently been coined first generation LOR, or LOR 1.0 (Rørvik, 2019). The second generation LORs were more independent, constructed to share learning resources across multiple LMSs. One example of such a LOR application in successful use is the North Carolina LOR (NCLor[4]). Today, the advances in learning resources hierarchies work in favor of sharing beyond the LORs themselves. Add to this enticing mix of workflow and productivity tools, and we see the third generation in the making, the LOR 3.0's (Rørvik, 2019). Work has since then commenced to define standards for how to make LORs work in practice, especially to reap advantage of the interconnectivity functionalities (Rodriguez & al., Dietze & Al, 2013).

In the early 2000s the Norwegian University of Science and Technology (NTNU) realized a need for a lightweight catalogue of learning resources, with dr. Carl-Fredrik Sørensen among the pioneers. This catalogue was conceived of as a metadata directory with information describing all learning resources in internal use at the NTNU, with pointers to the actual resources. The Norwegian library organization BIBSYS[5], a wholly owned subsidiary of the Ministry of Education, added actual storage of learning resources to a metadata service in a proposal for a Norwegian national LOR. NTNU was the first pilot of what quickly evolved into the first version of the learning resource sharing system DLR[6].

DLR initially targeted open access learning resource sharing, with a simple user interface accessible from electronic learning systems (LMSs), stimulating open access publishing across different LMSs. LMSs were connected to DLR via Learning Technology Interoperability (LTI) 1.0 integration. Functionality was simple: Files could be uploaded to the DLR store and Internet hyperlinks entered, together with descriptive data (metadata), such as title, subject etc. Dublin core was used as metadata scheme. After publication in DLR anyone using a LMS with DLR installed could search the metadata and (re-) use those DLR resources. The solution had a mixed reception however, ranging from great to inadequate and not needed, depending on their requirements and work styles.

The NTNU did a closer evaluation of LOR functionality in 2016, eventually teaming up with BIBSYS to adapt DLR to tougher requirements. This commenced in 2017. Challenges in user requirements were found with focus on drastically improving workflow and sharing for authors and administrators.

Oslo Metropolitan University (OsloMet) followed suit using DLR in the spring of 2018, due to interest from educational resource producers, as well as an institutional desire for efficiency and control in storing and sharing of educational resources. The main goal for the LOR implementation is that once published, at one place, resources are used, shared and maintained in all forms and iterations. OsloMet

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[4] NCLor, the North Carolina Learning Object Repository, https://explorethelor.org/

[5] BIBSYS later merged into the UNIT subsidiary of the Ministry of Education and Research

[6] DLR (of Unit/BIBSYS) is a Norwegian acronym for Digtal Learning Resources

now works with copyright, access issues and seamless integration between DLR and educational software such as LMS (Canvas) and others.

The University of Bergen (UiB) is considering DLR for LOR use, seeking a tool that supports storage, retrieval, publishing and sharing of a steadily increasing production of digital educational resources. Well-defined metadata are important, supporting easy content categorization, search and management, including sharing publicly or with a smaller group, with copyright handling. Interoperability with an open version of Canvas and the Communications content management system (CMS) is required.

With an expected reinforced embracement of DLR by the Ministry of Education and Research in 2019, integrating with other knowledge sharing siblings, DLR will be probably be a strategic component in HEI in Norway for the years to come.

4. DISCUSSION

4.1. The process of improving the DLR

The DLR had to prove it's merits during the internal evaluation of all eligible solutions at NTNU in 2016. Major internal stakeholders in the project *LOR at NTNU*[7] contributed to requirements.

From an institutional point of view, a well-suited LOR would simplify generation changes of LMSs by keeping most learning resources in the LOR, improving learning due to more and potentially better resources. Users discussed other success criteria of a learning resource sharing platform vigorously during the process. Representatives of the most important internal stakeholders were enrolled in a reference group of the projects, during 2016 and 2017. Among them were students, lecturers, faculty staff, support functions (multimedia etc.) as well as other learning resources sharing platform users.

A high number of demands and needs were expressed by the stakeholders. Limitations were identified implicitly by correlation and inspection of business requirements, business information and architectural issues. The outputs of these processes were expressed as requirements and architectural issues. A more commercial solution than DLR (among those eligible in 2016) was per NTNU policies in 2016 to be preferred, to tap into an established LOR ecosystem supporting the LMS Blackboard Learn acquired in 2016 at NTNU. If not, a partner solution with DLR from BIBSYS within the framework of the Ministry of Education and Research would be considered.

Eligible LORs were weighed against the requirements. No commercial LORs could handle the requirements out of the box or be adapted to do so. The DLR could handle most of the core requirements with modifications, at a modest cost covered by *LOR at NTNU* and BIBSYS.

In addition to a basic set of requirements more functionality would be added gradually, in close contact with users while keeping costs low. A good user experience was vital. The DLR was to blend into the user interfaces of all affected productivity systems of the user. Compound operations using DLR and one or more other system were to be simplified, if possible. Users would ideally not notice DLR in action, except as added functionality and better workflow in application systems such as LMSs.

4.2. User focus on learning resource productivity and workflow

A quick list with examples of requirements (as defined by developers and/or collected from users) are published on the LOR blog at NTNU[8].

Most wanted was *restricted access to internal resources*. Seemingly counterproductive to open access, restricted access actually helps authors to use DLR as the primary storage and publishing platform. This supports intuitive resource maturing, from internal to open. Once polished, internal resources in DLR are a license selection away from open access, automatically assigning a permanent handle and optionally a DOI if requested so by the author.

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[7] https://www.ntnu.no/blogger/lor-ved-ntnu/omprosjektet/ (Norwegian language)

[8] https://www.ntnu.no/blogger/lor-ved-ntnu/important-requirements-of-a-lor-2016-ed/

The Oslo Metropolitan University (OsloMet) is working specifically on licensing, copyright and access options, in close cooperation with prospective users. The input form makes the users aware of copyright issues, without hindering their motivation to upload and share learning resources.

The possibilities for improvement on the productivity workflow is also one of the reasons the university of Bergen (UiB) is looking into starting a DLR pilot this autumn. UiB can build on the work that has been done by NTNU from 2016 and OsloMet from 2018, and is currently establishing a test environment for the pilot in milieus aiming at creating and sharing digital learning objects that can set a high-quality standard nationally and internationally. To this end DLR will be a highly needed tool, with the easy to use license functionality, DOI coining and the accessibility across institutions. When colleagues can mature the content together in a restricted access space until it reaches the degree of quality considered eligible for use in tuition and to be shared openly as described above, this potentially solves multiple workflow issues at UiB. Along the possibilities implied by cloud management, the functionality in the LMS and a culture that values sharing, the new LOR technology can have transformative power.

In all cases, institutions can enable pre-publishing curation and/or moderation using DLR. The most obvious publishing mistakes such as copyright infringements are more often uncovered and avoided with the curation/moderation in service.

Integration with existing systems is an essential issue for institutions considering DLR. DLR battles "system-fatigue" blending into the institutional ecosystem, with their existing user interfaces.

Productivity support systems such as Mediasite® for video storage and streaming with integrated course information synchronization is implemented. One issue with this workflow is metadata quality. Those learning resources that are produced automatically during lectures do not always correlate nicely with information associated with the courses as found in the LMS, DLR or SIS, calling for metadata vetting before being easily findable and reusable.

With the integration of Microsoft Office 365® and/or Google Docs® resources can be displayed by DLR in the all supported LMSs giving a new dimension to handling, co-working and sharing of learning resources. DLR is integrated into Microsoft TeamSites (and from there, OneDrive) in a similar manner.

Another much appreciated productivity feature is *direct publishing* from personal video sources such as Microsoft® Skype. The usual productivity cycle of recording, storing, uploading and enhancing with metadata to the multimedia storage system is shortcut into one direct operation, with relevant metadata from the study information system (SIS) prefilled into the resource description.

4.3. Integrations - sources and consumers

The Unit DLR can integrate with any knowledge source or consumer such as automatic video acquisition systems, cross-platform search and easy and highly integrable use of open access and restricted access knowledge resources. This is implemented using a mix of components, as illustrated in Figure 1:

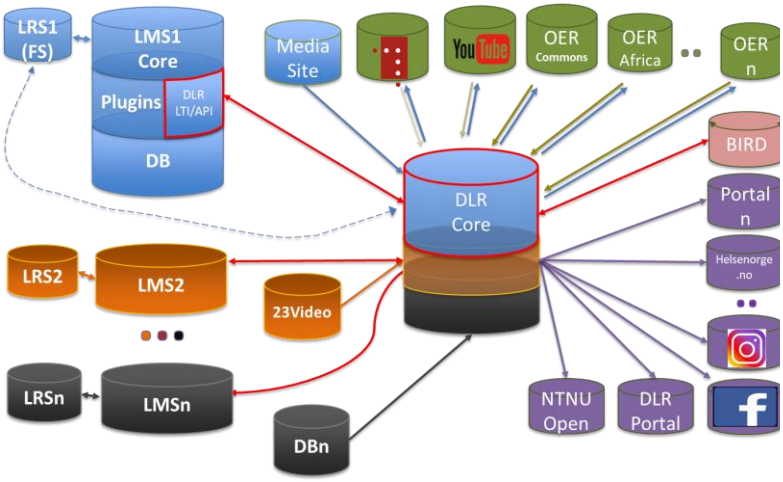

Figure 1: Present and future components of DLR as a LOR 3.0

The DLR is at the core, with three types of applications systems (LMS etc.) to the left, currently Blackboard Learn, Instructure Canvas, edX or It's learning. The blue institution's application system is shown with LTI integration for DLR. This provides the application system with publishing, search and reuse of resources inside DLR. Native application system APIs can give tighter integration, ideally offering full daisy chainable search

and storage integration, with publication, search and use of DLR material seamlessly available from within the applications system, blending in with internally published material of the application system itself. Equally important, metadata (and even data) can potentially be exchanged as illustrated with the connected green and purple boxes, with the Norwegian National Library, YouTube, OER Commons etc. in addition to portals and other information consumers and providers. And this architecture works: OsloMet gained access to over 800 educational videos into DLR from their already existing video storage system (23video) together with metadata and licensing information, integrating yet another production system into the workflow.

In the case of storing courses and other more complex learning resources, the demand may be to store both native learning objects (such as entire courses) as well as learning objects in standardized exchange formats at the same time. This would support both the best user experiences using native object formats for users of the originating application (typically an LMS), and at the same time support sharing of these resources with other institutions using standardized formats. The ability to define a application system independent sequential reading list within the DLR as a new learning resources was on the wish list as well.

4.4. Strategic concerns

On an institutional level, the dreaded commercial system lock-in of data containing application systems has been a major driver in the motivation for establishing a LOR. There are stories from institutions (NTNU/OsloMet) of high costs associated with moving resources from one LMS to another. While standards for data exchange between digital learning resource storage systems exist, they seldom work as seamlessly as promised, risking data corruption and/or considerable costs when trying to move data to new systems. The corruption or loss of learning resources moving from one system to another is troublesome, to say the least. Even worse is the potential situation of not affording to take care of previously produced learning resources, due to high costs. These generational losses may be coined the digital ättestupa (pronounced aettaestupa, in Icelandic/Norwegian/Danish *ættestup*[9]).

The tender rules in Norway and the EU are contributing to this situation, allowing for contracts with a duration basically limited to four years. An option for extending contracts with two plus two years is often added, for a total maximum of eight years[10]. In sum this implies extra costs, data corruptions and losses that incur periodically, typically every eight years.

A method for conserving learning resource is called for, within a timespan of decades and not years. The obvious strategy is to store data in a way that gives full control and all options open for the data owner. This leaves few other options than a do-it-yourself solution toda, using the very best principles of software design available. One may opt for an exception to the rule of competition within the field of digital learning resources storage, given a commercial vendor willing to partner with the HEI sector for decades to come. Such vendors would have to be closely cooperating with customers trying to close the gap between requirements and solutions at an affordable and not least predictable cost.

Participating institutions want DLR to act as an replacement of LMSs' storage. The owner of higher education institutions in Norway (KD) requires that data are created once-only and reused elsewhere. DLR satisfies these requirements, placing itself at the middle tier, accessible from applications systems (LMS, eAs etc.) at the upper tier offering flexible store and re-use functionalities, pointing to actual storage at the lower tier.

The ideal goal is to even be able to replace the DLR entirely with a new LOR system, without affecting the users, and to be able to replace the underlying storage system, without affecting the DLR itself. Given these rules, replacing the storage system is indeed possible obeying by the rules of open markets and competition. In this spirit, commercial software at certain points in the compound solution will certainly be needed and possible at any given point in time, but only when they can be replaced without wreaking havoc to the underlying requirements of safely storing and re-using the digital learning resources.

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[9] The knowledge ättestupa: The loss of learning resources etc. when systems are phased out/replaced.

[10] Example of public contract following an open tender in EU, with maximum duration of four years: http://www.europarl.europa.eu/trad/etu/models_contrat_cadre_services_110100_en.doc

The technical solution is certainly only one of several prerequisites for DLR to become a successful, first choice operating LOR. Sharing culture and change management is vital to succeed in achieving the goal of extensive sharing and reuse of learning resources.[11]

Successful organizational implementations of DLR require that the individual learning resource authors (lecturers, etc.) will have to actually produce learning resources stored in DLR. When using DLR totally transparently with selected perfectly integrable LMSs and other application systems, this will always be the case. Even so they will have to decide to actually share the learning content produced. Among these success factors are the rules and guidelines for collaboration and sharing, motivational factors like rewards and incentives, a contributing academic and educational community of peers, pre-existing learning resources and the perceived usefulness of the technical tool itself (Margaryan & al, 2007).

Sharing of experience and collaboration between organizational managers at the different institutions introducing DLR into their organization may be both useful and important. Using the LOR as *the* sharing medium for handouts and information material in conjunction with the organizational implementation projects implementing DLR or other LORs can be a good idea. The managers can rework and reuse the material at different institutions with adaptations suited to their institutional needs. In this way managers in charge of the implementation at the different institutions, such as those at the university library, the study administration or central office in their organization will earn useful experience on how the technical solution works and best can be used.

4.5. Technical implementation and architectural concerns

The architecture of DLR is based on the "Digital Object Architecture" as defined by DONA Foundation (see text box). The core elements are a metadata collection (*the registry system*) and a content collection (*the repository system*), with a handle to serve as a persistent identifier (PID) (*the identifier/resolution system*).

> **A digital object** (DO) is a sequence of bits, or a set of sequences of bits, incorporating a work or portion of a work or other information in which a party has rights or interests, or in which there is value, each of the sequences being structured in a way that is interpretable by one or more of the computational facilities, and having as an essential element an associated unique persistent identifier.
>
> *https://www.dona.net/digitalobjectarchitecture*

In the registration process, DLR asks for the resource (file or URL), before the registration schema is presented. This allows DLR to extract metadata on attributes like title, content type and possibly other fields. If it is a URL pointing to machine-readable metadata or if the resource contains integrated metadata (for example an mpg-file), this is used to prefill the schema. Based on this information a partly filled out suited metadata form can be presented, corresponding to the resource at hand.

DLR aims to preserve any metadata that are considered valuable, and the content object may be a file, a collection of files or a URI to some external content. Selected parts of the metadata (partly Dublin Core) and possibly text extracted from the content is used to build a search index, enabling the user to retrieve stored content.

DLR has automated *agents* that traverse resources and extract textual information, subsequently used by an indexing agent to improve the resources findability. The author registering a resource may request that the curator mint a DataCite Document Object Identifier (DOI)[12]. A curator (or any other user with elevated rights) can then mint a DOI on any registered resource. In addition to providing a permanent resource identifier, this improves findability being indexed by most global search engines and connected OER hierarchies.

Users with elevated rights may upload a json file (following a defined pattern) with metadata and links to resources, that DLR will digest in real time and use to publish new resources.

There are several production workflows in DLR that enable user friendly and efficient registration and publication of new resources. Examples are workflows that enable the user to push video files into a

[11] Investigation of access to learning resources, Unit, May 2019

[12] DOI: https://datacite.org/dois.html

backing streaming service or to pull existing published video files out of the institutions streaming service, from the DLR user interface, tightly integrated with the selected LMS. The teacher may not even know that she uses DLR or a streaming server at all.

DLR enables a teacher to publish newly created documents from within Microsoft Teamsite® to students following a course at the institutions LMS as a *one-stop-shop* function, that emulates as an integrated part of a Teamsite user interface.

Each resource in DLR has an internal presentation and an external *landing page*. The internal view is where the owner of the resource has access to maintain it and where other users will have access to the resource, if they browse or search in DLR. Any use of the handle or DOI will always lead to the landing page. The landing page contains metadata, access information, licensing and a link to the location of the resource. The resource will also be viewed directly in the browser, if the current instance of DLR is configured with an active viewer matching the current resource type.

The current version of DLR supports insertion and consumption of resources in Blackboard Learn, Canvas, It's Learning and edX through a tight integration in the page builder interface and in presentation of the pages. DLR also presents a default html code snippet that can be used to present supported resources in blogs and other html enabled environments.

Technical implementation of the current version of DLR is realized as an event-based micro-service application on Amazon AWS, with S3 as default storage. The service layer is undergoing some rewriting to enable delivery of an API that allows 3rd party agents access to DLR. Current development aim to improve our compliancy with "Digital Object Interface Protocol Specification"[13], to further improve our openness and to support more objective layers between software solutions, enabling cheaper integrations. Establishing an API for any 3rd party will enable both the user and institutions to programmatically incorporate DLR into other production and consumptions workflows and not reserve this ability to UNIT only, as it is today. To enable integrations of a *plug'n'play* scenario (from the viewpoint of a developer), all future request for procurement (RFP) processes for LMSs and other systems should highlight this type of needs. Integration is a biparty activity, where both parts must be obliged to participate to reach the end goal.

4.6. Challenges and possible solutions

Nationally, sharing of digital content in general in the HEI sector is identified as a challenge that needs to be better addressed, in addition to securing storage and maintenance over time. The Ministry of Education and Research asked Unit in the autumn of 2018 to investigate the main challenges regarding storage needs in the upcoming future. The end user's needs – those of the student, the teacher and the researcher - regarding storage solutions was the topic of the investigation. In the report, the current situation is described as somewhat confusing with many suppliers of various storage services that partly overlaps, with user groups not getting their storage needs covered in a satisfactory way. LOR technology fits well into this picture and will hopefully solve a substantial portion of the storage and content handling issues.

The technology driven possibilities for co-creation and sharing give promise of increasing efficiency and productivity. Sharing of digital content may also intrinsically increase the complexity associated with content handling. There is a need for more knowledge about reuse of already shared digital content, as well as how to share one's own content, and this must be addressed when introducing a LOR such as the DLR into the organization.

Implementing DLR in a new institution is a challenging process, requiring integrations to multiple computer systems, and calling for organizational and cultural changes. End-user training is called for, even when reusing tools already in place and letting DLR mimic the look-and-feel of existing systems being integrated into.

DLR places itself at and between the university library, educational departments, multimedia department, lecturers and researchers. This implies organizational challenges, such as ownership of the learning resources, the system and the services involved. Bridging the gaps between libraries,

[13] https://www.dona.net/sites/default/files/2018-11/DOIPv2Spec_1.pdf

educational departments etc. can be challenging. A crossbreed of the stakeholders mentioned could indeed be the ideal institutional owner of a strategic LOR effort.

Introducing DLR in an organization, it may be wise to not expect miracles from day one. The author is a good starting point when marketing DLR as a integrable and inseparable part of the primary workflow of each and every learning resource. The built-in sharing mechanisms of DLR would then be just one check-mark away in the LMSs etc. from actual open publication. In addition, importing whatever relevant learning resources that might entice the lecturers (and hence authors) to have a deep look into DLR from the start on will stimulate even before publishing starts. This can be OER resources, or indeed imported pre-existing resources from the organization itself. Organizations should stimulate the desire to share learning resources in any way imaginable, counteracting the reservedness sometimes found among lecturers from exposing their own learning resources outside their own courses.

As previously noted, it is important to make the publication and reuse process as simple as possible. Given the nature of knowledge dissertation today, it is well known that learning resources are not built entirely from scratch but are collected from bits and pieces retrieved and transformed using books, articles and sources on the Internet, to name a few. In this context, LOR experience tells that LORs are often preferred before search systems at large (Elfekey & Elbyaly, 2016).

Cooperation between institutions with a common educational agenda should further propel the creation of what could be a vital marketplace for learning objects, in the auspices of DLR and similar systems. This may eventually lead to a kind of open-source collaborative community, possibly calling for governmental regulations to stimulate for optimal sharing and use of resources.

Fear of copyright infringement will have to be discussed and assessed, using curation as one measure to reduce the fear. At the same time enhancements like AI (Artificial Intelligence) searching for copyright infringements, identifying copyrighted material and acting on uses of such in learning resources will greatly reduce this issue. In addition, users should be able to report infringements (and other cases of misuse) to the editor. New regulations in the EU must not hamper the use (and reuse) of learning resources, and rather be met by the DLR, encapsulating the problem and offering methods for coping with these issues, helping users and institutions alike.

4.7. Additional development

Future development plans call for improved automatic metadata capture and generation of metadata such as subject and other classifications. The vision is to change the registration process into a validation step, not a typing experience. One example is simplification based on former works by the author. Through the single sign on mechanism, DLR will know the *open researcher and contributor ID* (ORCID)/*international standard name identifier* (ISNI), given proper authorization to do so. This may give DLR access to both local and external registered content, to prefill sensible metadata suggestions in registration forms. Other forms of prior knowledge can be used even more fully to prefill registration forms with metadata. Key attributes such as course information and content type can be retrieved from the study information system (SIS). Metadata or textual descriptions found in many resources such as title, keywords, abstracts etc. serve as prefilled learning resource descriptions in the registration form. Future development can utilize artificial intelligence (AI) to create metadata using analysis of content and usage, to name a few. Through open access, collaboration with external search systems may give additional benefits, if employed properly.

Any sufficiently API-equipped productivity support system can be integrated. Active resources such as simulators, digital twins, questionnaires, comms tools etc. are easily added. Such resources may reap advantage of LMS-specific functions, integrating the resources themselves and the LMS. One potential example is to enable active resources to interact with conditional release mechanisms such as in Blackboard Learn to give the students more adaptive learning.

In addition, stimuli for increasing the publishing of learning resources should be added, such as mechanisms rewarding publishing. Authors may request to be reviewed by peers and students, which will give credit to the author, and formal meriting from the institution of the publicist, if condoned by the institution of the author. When applicable, publication points could be awarded, for instance based on the number of learning resources published, number of views, popularity, peer reviews, number of co-authors (institutions, nationalities) and versions (derivatives) built upon their original work, as well as other applicable factors.

Implementing the DLR as a LOR 3.0 means connecting to OERs, social media and other interesting application services as well as better workflow support. Application systems such as LMSs, MOOCs etc. should see a unique opportunity in embracing LOR 3.0 systems fully and extend their APIs to support functionality such as storage and search redirection in LOR services fully. This may facilitate an totally immersive and transparent user experience for the LMS users, tapping directly into the potentially nearly unlimited learning resource collections of a full-fledged LOR 3.0 such as a soon-to-come new version of DLR. The LOR 3.0s will hopefully work more transparently and user friendly if they are able to integrate more fully into the LMSs in other aspects as well, using whatever integration techniques available.

The Ministry of Education and Research requested a report[14] from Unit 1st of May 2019, with a recommendation on how to implement a national LOR. Unit has, through a process with involvement from several of the sector's stakeholders, concluded that DLR is the best option to establish a national LOR. Further development rests to a large degree on what the ministry decides during the spring of 2019, including funding.

The Ministry of Education and Research also requested a report[15] from Unit 1st of November 2018, with a recommendation on how to implement a National Research Archive (NRA) (in Norwegian: Nasjonalt Vitenarkiv). Unit recommended to build this archive on the technical infrastructure that is established to deliver DLR. This report also recommends the national current research information system (CRIS-system) Cristin (https://cristin.no) to use NRA as its data source for its' future reports and establishing four national master data sources for the entities person (author), organization (institutions), (research) project and application (for approvals to run and funding of research projects).

Unit delivers in addition an institutional archive (https://unit.brage.unit.no) to more than 60 institutions and a research data archive (https://bird.unit.no). The current plan is to merge all repositories into a joint technical infrastructure, with separate user interfaces to support different user needs. A key interest is to allow reuse of any resource, across the different usage domains such as education, research, administration and reporting, without the need of multiple duplicate manual registrations. The use of common master data sources, in the different registration process of resources, will increase the quality (of granulation and validity) and value of future reports based on this source of data.

5. CONCLUSIONS

DLR is an application and storage system neutral, second generation learning object repository (LOR 2.0), supporting third generation (LOR 3.0) functionality when added. It interfaces with application systems (LMSs etc.) and storage systems using well-documented standards for interchange of data and metadata. DLR not only bridges open access and restricted access resources, but offers better productivity, thanks to its close integration with productivity systems such as video production systems. A simple and intuitive user interface is blended into the application systems in question and enhances its functionality. The DLR is enhanced with metadata transferred from the study information system (SIS) and other relevant sources, among others suggesting descriptive data while entering new learning resources. The gap between internal resource production, consumption and open access is bridged, optionally interfacing with open educational resources and other learning resource consumers and producers outside the DLR. Any digital resource (even software) is supported. DLR handles licen-sing and can support commercial resources if required.

Future development contains plans for improved automatic metadata capture and generation of metadata such as classification, subject etc. The vision is to change the registration process into a validation step, not a typing experience. Artificial intelligence (AI) can be used to complement metadata, using info from content and usage. Stimuli for increasing the publishing of learning resources should be employed, both informally such reviews by peers and students (if enabled by author), and formally meriting the authors from the institutions.

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[14] http://hdl.handle.net/11250/2595979

[15] http://hdl.handle.net/11250/2582373

Application systems such as LMSs have a unique opportunity in embracing LOR 3.0 systems fully, with APIs supporting functionality such as storage and search redirection from the LMS to the LOR 3.0, giving an immersive and transparent user experience, tapping directly into the potentially vast learning resource collections of a full-fledged LOR 3.0. Vendors doing this will be the number one choice of any organization going for a full LOR 3.0 experience. The LOR 3.0s, such as a coming version of DLR, will work more transparently and user friendly if they are able to integrate fully into the LMSs, using whatever integration techniques available, both open and proprietary. On the resource provider side, those vying for a greater audience will get it by connecting to DLR directly (potentially even for commercial resources).

Organizational issues ultimately decide the success and failure of a LOR such as DLR. Management commitment, sharing culture and stimuli such as meriting will contribute to success.

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