OERu's Delivery Model for Changing Times: An Open Source NGDLE

Dave C. Lane and Claire Goode

Abstract

The OERu (Open Education Resources universitas) is an international consortium of 30 publicly funded institutions, which, with the OER Foundation, form a network across the world. OERu presently offers first-year post-secondary courses assembled from OER as micro-courses with pathways to gain stackable micro-credentials towards academic credit for university qualifications.

OERu, adhering to “open” principles, has created an open source "Next Generation Digital Learning Environment" (NGDLE) to meet the needs of learners, consortium partners, and OERu collaborators. The NGDLE is an example of a global computing infrastructure created to reach learners wherever they are. It is a distributed, loosely coupled component model, consisting entirely of Free and Open Source Software (FOSS). All OERu services are hosted on this fully open source technology infrastructure.

This approach has significant advantages and, if emulated by OERu partners and other academic institutions, could both enhance the digital services used in education and substantially reduce costs for their institutions. The NGDLE can also increase the autonomy and resilience of technical solutions, while providing unprecedented technology-related learning opportunities and agency for learners and educators alike.

This paper describes the technology infrastructure and explains some of its advantages, while noting the challenges it presents. We will offer a functionality, scalability, and cost profile of our implementation, currently capable of supporting many thousands of learners, on an IT infrastructure budget of less than $10,000 per year.

Beyond the cost benefits and technical efficiency of the OERu NGDLE, we review some pedagogical opportunities it presents and the solutions we have implemented in response.

The OERu philosophy embraces 'learning on the Internet', rather than learning via any particular platform. In this way, learners have more control of their course artefacts, rather than them being locked into an institutional system, or losing access when the course is completed.

Alongside benefits for the learners, educators developing OERu micro courses build new skills in collaborative wiki editing and writing for the web, using open source tools, finding openly licensed content, and adopting pedagogies embodying 'free-range learning'. Writers are pushed to consider the audience more than ever before, knowing that OERu learners are spread across six global regions: content needs to appeal to, and be clear to a global audience, many of whom are not native English speakers.

The OERu international network also demonstrates its potential by collaborating on content writing, assessment moderation, and idea generation, to ensure a meaningful experience for OERu learners.

Key Words: open source, learning environment, OER, equity, ICT

Introduction

The OERu (Open Education Resources universitas) is an international consortium of 30 publicly funded institutions, which, with the OER Foundation, form a network across the world. The OERu presently offers first-year post-secondary courses assembled from OER as micro-courses, with pathways to gain academic credit for university qualifications.

Adhering to 'open' principles with their emphasis on the '5Rs of reuse' - Reuse, Revise, Remix, Redistribute, and Retain (Wiley, 2014b) - themselves inspired by the four essential freedoms of Free Software (Free Software Foundation, 2019; Wiley, 2014a), the OERu has created an open source 'Next Generation Digital Learning Environment' (NGDLE) to meet the needs of learners, consortium partners, and OERu collaborators. All OERu services are hosted and delivered via this fully open source infrastructure.

This approach has significant advantages and, if emulated by OERu partners and other academic institutions, could both enhance the digital services used in education and substantially reduce costs for institutions. The NGDLE can also increase the autonomy and resilience of technical solutions, while building digital skills for learners and educators alike.

This paper describes the technology infrastructure and explains its advantages and challenges. We review the functionality, scalability, and cost profile of our implementation, currently capable of supporting thousands of learners, on an IT infrastructure budget of less than $10,000[1] per year (about $2 per learner/year), and which promises to scale to millions of learners with only modest IT budget implications (under $1 per learner/year).

The OERu's open source NGDLE

By 2014, 99 percent of universities in the United States alone were using a Learning Management System (LMS), with 74 percent of staff feeling they were "useful instructional tools" (Baule, 2019). However, the LMS is "focused on the institution and the course" (Conde et al., 2014, p. 189), rather than placing the learner at the centre of their learning experience.

[1] All costs are in US Dollars unless otherwise noted.

In 2014, EDUCAUSE ran a series of focus groups investigating digital learning environments and how they could better support learning and teaching (Brown, 2017; Maas, Abel, Suess, & O'Brien, 2016). This research resulted in the April 2015 white paper (Brown, Dehoney, & Millichap, 2015) on 'next-generation digital learning environments' or NGDLE. As Brown et al. highlight, "higher education is transitioning from the transmission model of education to one built on concepts such as active learning, personalization, hybrid course designs, and new directions for measuring degree progress" (2015, p. 3), calling for "an ecosystem of sorts" (ibid.). The white paper acknowledges that "the challenge for the NGDLE is supporting this diversity while retaining the necessary technological coherence. But in this challenge also lies the opportunity. Clearly, we need to invent new architectures that support a digital confederation" (Brown et al., 2015, p. 4). Brown (2017) urges institutions to think beyond their digital learning environment towards "strategic destinations…, new directions and opportunities", and this is one ability and strength of the OERu.

The OERu has determined one way of supporting learners to develop digital and associated learning literacies for the 21st century is to employ precisely the technologies they need to build digital fluencies for learning today. This contrasts with the cloistered digital experience of an LMS environment. The OERu approach of 'learning on the Internet' has more moving parts and is less constrained than an LMS environment, but that added complexity also offers advantages:

- Collaborative content creation, with detailed version control, not limited to participants from a single institution.
- Learners can maintain control of their own work (digital artefacts), both during and following study.
- OER materials can be shared among institutions, regardless of which LMS, if any, they have adopted.
- Learners actively employ and experience the technologies, conventions, and practices of the 'real' digital world, rather than a model environment.

The learner-facing part of the OERu's NGDLE is constantly evolving; a snapshot is shown in figure 1:

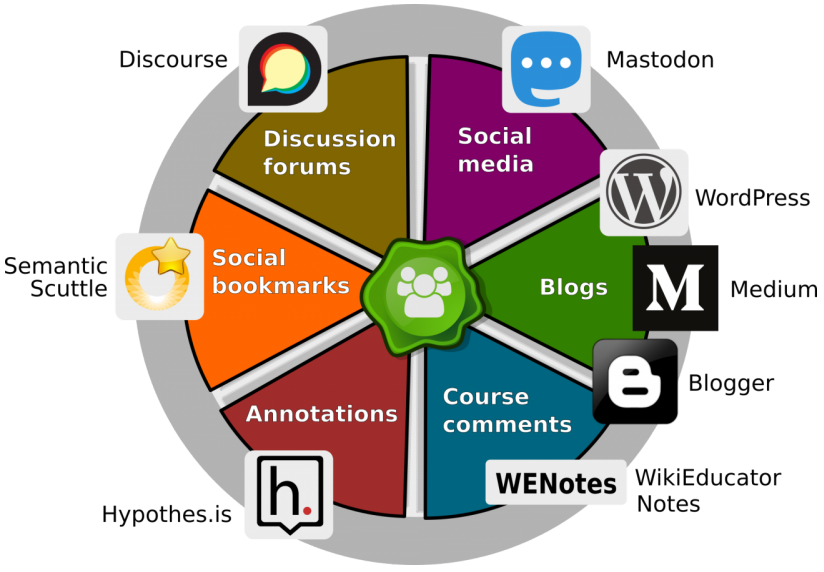

Figure 1: Services currently making up learner-facing parts of the OERu's NGDLE.

These services are hosted either by independent Internet communities or on the OERu's fully open source infrastructure.

- ***Mastodon*** is a communication tool and OERu's alternative to *Twitter*, allowing posts of up to 500 characters. It is non-commercial, unlike *Twitter*, so there is no advertising or threat to learner privacy (Mackintosh & Cooper-Taylor, 2018b; Mastodon, n.d.).
- In **Blogs**, learners can post in more depth and include other media such as images, audio, or video. We encourage the use of three gratis blogging tools – *WordPress*, *Medium*, and *Blogger* – but learners can use any blogging tool they wish. We aggregate learner posts by means of a post hashtag or label.
- ***WEnotes*** is a micro-blogging tool included on most course pages so that learners can make comments or ask questions right inside the page (Lane, 2017 (August); Mackintosh & Tittsler, 2013).
- ***Hypothes.is*** can be used to annotate or discuss any published web page or PDF document accessible publicly via the browser, including the ability to organise research, and take personal notes (Cooper-Taylor & Mackintosh, 2018a; Hypothesis Project, n.d.).
- ***SemanticScuttle***, a social bookmarking tool, enables learners to add, annotate, edit, and share bookmarks of web documents (Cooper-Taylor & Mackintosh, 2018b; Slashdot Media, 2019).
- ***Discourse*** is the OERu's learner forum tool for persistent, discoverable discussion and collaboration (Civilized Discourse Construction Kit, n.d.; Mackintosh & Cooper-Taylor, 2018a).

The OERu component-based platform uses its *WEnotes* aggregator[2] (internally developed Free and Open Source Software (FOSS)[3]) to create a feed of learner posts and comments originating from all of these distributed interaction technologies.

The OERu's NGDLE is an example of a global infrastructure created to reach learners wherever they are. It is a distributed, loosely coupled component model, consisting entirely of FOSS. It demonstrates that, by accepting a small increase in architectural complexity (relative to conventional 'all-in-one' monolithic Learning Management Systems), the OERu's NGDLE can achieve better functionality, flexibility, and scalability, as well as an advantageous cost profile. It also reduces the OERu's liability by achieving technological, commercial, and geographic diversity in its infrastructure.

Advantages and challenges of a component-based open source infrastructure

The challenge of complexity

When compared to conventional Learning Management Systems, the OERu's NGDLE *appears* more complex. Instead of fitting everything into a single platform as an LMS does, the NGDLE comprises an ever-evolving array of largely independent FOSS technologies, each developed and maintained by its own communities, working in concert for the benefit of all.

Rather than expertise in a single LMS product, running the OERu's NGDLE requires a capable technology 'conductor', orchestrating dozens of technologies that work together. Unlike typical makers of proprietary software, who have an incentive to lock out would-be competitors, often

[2] See https://git.oeru.org/oeru/wenotes-aggregator

[3] The OERu uses the term 'Free and Open Source Software' or FOSS to acknowledge the crucial 'Free Software' principles (Free Software Foundation, 2019) of what is now more commonly called "open source software" (Open Source Initiative, n.d.). The term 'open source software' downplays these principles, and focuses instead on the development methodology.

purposefully incompatible to stymie them, FOSS developers have no incentive *not* to employ open standards and design conventions, greatly facilitating integration and, perhaps surprisingly, consistency of approach. FOSS components, then, generally play harmoniously with one another.

A technologist familiar with these conventions and open standards can rapidly and reliably deploy NGDLE technologies, combining them into, from a learner's perspective, a well-integrated, consistent suite of learning and collaboration services (Brooks & Pomerantz, 2019; EDUCAUSE Learning Initiative, 2015). The underlying complexity accompanying this technological diversity is, then, not nearly as confounding as it might first appear.

Functionality advantages

A component-based approach means selecting only the 'best-of-breed', often from among several mature FOSS contenders (such as in the collaborative chat space, where contenders include *Mattermost*, *Rocket.Chat,* and *Matrix*). This means that specialised platforms for each niche, including, for example, learner identity management, course presentation, document management, chat services, discussion forums, collaborative OER assembly, email automation, open badge management, website annotation, and course assessment, can all be sourced individually based on their fitness-for-purpose. This is in contrast to the conventional practice where the only components available are those specifically built for the LMS (whether FOSS or proprietary) to which an institution has committed itself; those components are seldom best-of-breed.

Flexibility advantages

A major advantage of the OERu's NGDLE is the ability to replace existing components whenever we find a new functionally similar component that we think offers advantages for learner usability, application stability, maintainability, scalability, and other criteria, allowing rapid evolution of the overall system. We can make these component 'swaps' because FOSS applications (like non-proprietary *Legos*®) typically implement open standards for integration. These include interfaces and protocols like HTTP/HTTPS (for encrypted web content transfer), OpenID/OAuth2 (single sign-on technologies), WebSockets (for live updates to content like social media feeds), and various others.

Through FOSS project website feeds, chat platforms, mailing lists, and social media, we continuously monitor existing, emerging, and novel FOSS solutions relevant to our NGDLE. When a better component for a particular area of our infrastructure emerges through our testing, we can create complete local replicas of our entire infrastructure (minus private user data) at no cost, thanks to its FOSS nature. We can then trial swapping an existing component for a new one, testing to ensure that the change is possible and the benefits outweigh the costs.

Scalability advantages

The OERu has started small, with just over two thousand learners from 113 countries participating in courses during our minimum viable product phase (May 2018-May 2019). This has placed a modest load on OERu infrastructure, while allowing OERu's technical team to validate that everything is working as intended. In many software implementations, even these small numbers would challenge the ability of normally available infrastructure to supply a usable service, namely one that is fast, seamless (performing the same way across platforms, for example), and reliable enough to feel trustworthy and credible to learners.

A major advantage of this loosely coupled component model is that each component is in active use in other contexts. Every component has already had its 'trial-by-fire' at 'Internet scale', serving many thousands or millions of concurrent users, and has already evolved to meet those challenges.

Although the applications chosen are all products of different communities, different developers, and different technologies, they all adhere to a set of well-tested, robust, and scalable Internet software service patterns. OERu's key technologies, such as *MediaWiki* (the technology on which *Wikipedia*, and our *WikiEducator* are built (WikiEducator, 2016)) *WordPress*, *Drupal*, *Silverstripe*, *Mastodon*, *Discourse*, and *Mautic*, among others, are well proven, even at the scale of tens of millions of users. All have separate data stores (mostly databases, including *MariaDB*, *PostgreSQL*, *MongoDB*, *CouchDB*, and *SQLite*), themselves decoupled from the containers doing the computing, usually running scripting engines (OERu components make use of *PHP*, *Ruby on Rails*, *Python*, and *Node.JS*). Data is manipulated in a 'stateless' way - with the software's logic not having to reside on a single piece of infrastructure. This makes them inherently amenable to scaling up just by adding more servers. These applications all serve up data to - and take interactions from - users' web browsers with the native language of the Web - open standards compliant HTML5 (comprising HyperText Mark-up Language (HTML) mark-up, Cascading Style Sheets (CSS) for styling, and JavaScript for in-browser client application functionality).

This shared practice is the culmination of many years of testing at Internet scale, and makes it possible for the OERu to simply 'dial up' all of these services as required by adding more low-cost commodity computing containers (facilitated by the use of *Docker*, a FOSS technology allowing self-contained computing 'sandboxes' that can easily be created, copied, removed, or moved among computing environments).

Cost advantages

None of the technologies in the OERu stack incurs licence fees. The only associated costs are commodity-hosting infrastructure costs, and staff time to set up and maintain them. This means that the cost of a given set of components is a low fixed cost, sustainable even with a remarkably low number of learners, and which, crucially, *does not increase significantly as learner numbers grow*. This means the cost of the OERu's learner number going from a thousand to a million (a hundred-fold increase) might only carry a five to ten-fold infrastructure cost increase. That is extremely attractive.

Return on (open source technology) investment

Return on Investment (ROI) can be achieved in a number of ways, including through investment to improve productivity, by reducing costs, or, ideally, a combination of both. The OERu has created and maintains its capabilities with a very small budget for infrastructure and targeted development. This is accomplished through four key principles:

1. Using commodity FOSS hosting, allowing for rapid movement between hosting providers with minimal trouble or disruption to services.
2. When using Software-as-a-Service (SaaS) solutions, OERu only uses FOSS options that provide a safety valve if the pricing model/service does not suit present needs. (Currently, the large-scale video conferencing system *Zoom* is the sole proprietary software service the OERu employs, with no functionally comparable FOSS alternatives available at present). This largely removes vendor lock-in.
3. Ensuring any external purchased service is fixed price and does not increase with number of users.
4. Accounting for internal staff time in cost of ownership calculations.

The OERu currently uses five hosting providers on four continents, all commodity FOSS platforms without proprietary features. The OERu does not exceed the (quite generous) in-built data and storage allotments, so costs are fixed and predictable.

The OERu's entire annual infrastructure/IT costs can be summarised as follows (values approximate, in US dollars):

Hosting infrastructure:	*AWS* ($4000) + *Hetzner* ($440) + *DigitalOcean* ($900) + *Catalyst Cloud* ($0) + *Microsoft Azure* ($0) = $5340
SaaS:	*Zoom* ($180) + *Kanboard* ($360) = $540

Total annual software and infrastructure budget: $5880

Some of the OER Foundation's hosting infrastructure costs are covered by sponsorship: we receive up to NZD 500/month sponsored hosting services from the NZ-based hosting provider, *Catalyst Cloud*, who offer a fully open source cloud-hosting infrastructure (Catalyst Cloud, n.d.). We also receive a charitable organisation hosting grant of $3500 from *Microsoft Azur*e.

Because OERu runs the FOSS *GNU/Linux* on all servers (we use both *Ubuntu* and *Debian* distributions), there is no cost involved for the operating system, running as many as required without incremental cost. Only the cost of the technologist's time and the relative computing resource requirements are variable. However, those costs do not increase at anywhere near the same rate as user numbers. For example, ten times more users might require twice the staff time (a linear increase would be ten times the staff time), and perhaps twice the direct computing infrastructure resources.

Case study: SaaS and the value of open source

Mautic is a FOSS "marketing automation" tool (Acquia, 2019), chosen to automate email communications with both existing and prospective learners and partners.

Initially, to test its functionality, the OERu opted to use the $30/month entry-level SaaS offering from Mautic.com, which allowed us a single login to gain immediate access and test *Mautic*'s fit with OERu requirements. This service allowed for up to 2000 contacts, with a modest cost increase for additional contacts.

Mautic.com salespeople contacted the OERu after a few months to say that their pricing model was changing, and that our costs would rise by more than ten times to $500/month, with a more substantial increase for additional contacts. For example, ten thousand contacts would cost $1000/month. This placed the OERu in an uncomfortable position, having found *Mautic* to be a very useful tool that we wanted to make central to our services. Because the *Mautic* application itself is FOSS, however, unlike with proprietary SaaS offerings, the option of self-hosting was available to us. It took less than two days to implement and document a self-hosted OERu *Mautic* instance (Lane, 2017 (March)). This places a negligible additional load on OERu infrastructure, and we benefit from its capabilities being continually improved by the *Mautic* developer community. It only takes around one hour per month of the technologist's time to keep up with changes. Moreover, the OERu has subsequently joined the *Mautic* development community, contributing to improving the platform to ensure it meets our needs.

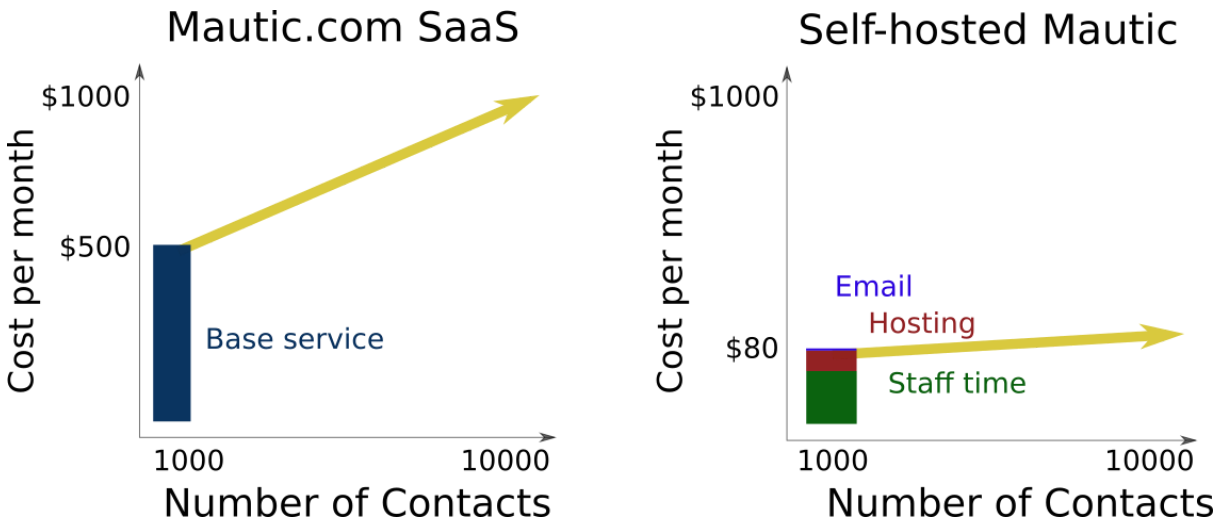

Figure 2: Mautic cost per contact comparison between SaaS and self-hosted.

The self-hosted cost profile for *Mautic* is also far more favourable. Cost estimates include technical staff time (typically about $70/month), a component of hosting infrastructure, and outgoing email costs. The approximately 30 thousand emails sent over the past year using *Mautic* via AWS' '*Simple Email Service'* cost the OERu less than $1.00 in total. Overall, as shown in Figure 2, the per-month cost comparison for 10 thousand contacts of SaaS vs. self-hosted is about $1000 vs. $80, or an annual saving of approximately $11,040 from a total of $12,000, a saving of 92%. That saving is greater than the OERu's total annual infrastructure budget, and will only improve as learner numbers grow. This validates the FOSS self-hosted approach, and represents a huge opportunity, particularly for higher education institutions in emerging economies.

The benefits of diversity

As with any living ecosystem, lack of diversity in technology infrastructure increases risk. A technology monoculture (that is, a single-vendor proprietary computing environment that only supports integration with software created by that vendor or its designated partners) means that a security failure can render an entire infrastructure vulnerable to hostile exploitation by third parties. Similarly, a *supplier failure* (where a supplier goes out of business, is acquired, alters or discontinues a key product, or changes its pricing model) can render an entire infrastructure unsupportable, or, in the case of pricing changes for proprietary software or services, economically unsustainable. If the institutions making that software available to their learners cannot remedy that liability by migrating to other technology without, for example, loss of data or access, this can have a massive negative effect both on learners and on institutional reputation.

To mitigate this risk, the OERu has no proprietary supplier dependencies for learner-related services; our only commercial relationship with technology providers is for commodity hosting of *GNU/Linux* computing infrastructure. As such, we can transfer our entire infrastructure from one provider's offering to another's with minimal downtime, no data loss, and minimal cost.

Finally, as the OERu's home country New Zealand has seen with recent environmental (earthquakes, fires, and floods) and social disasters (terrorism), we are acutely aware that lack of geographic diversity is a major infrastructural liability. We have chosen to host our web services in multiple facilities around the world. The aggregate cost of those services is about $10,000 per

year, including the value of sponsored hosting services we receive.

Due to recent policy changes with one of those infrastructure providers, actively disadvantaging FOSS solutions, the OERu has moved some of its services to other infrastructure; again, something we can do with minimal time, cost, or risk, and with little, if any, disruption to our learners.

Pedagogical opportunities

With the OERu philosophy embracing 'learning on the Internet', rather than learning via any particular platform, learners have complete control of their course artefacts, rather than them being locked into an institutional system, with "participatory technologies [being] integral to openness" (Blomgren, 2018, p. 57). This control enables learners to "navigate their own journey through content to achieve desired learning outcomes" (Bossu & Willems, 2017, p. 24), and is the first principle of the 'Open Empowered Learning Pedagogy' (Smyth, Bossu, & Stagg, 2016) framework. UNESCO (2019) highlights that:

> Further to the adoption of… a standard-setting instrument on international collaboration in the field of Open Educational Resources (OER)..., UNESCO is developing a draft text for a UNESCO [Recommendation] on OER that will be discussed at the 40th session of the UNESCO General Conference in 2019.

For learners using OER, advantages include the development of self-directed skills (Lin, 2019), textbook cost savings (Blomgren, 2018; UNESCO, 2019), a variety of dynamic OER materials in different languages (King, Pegrum, & Forsey, 2018), mobile learning (Chib & Wardoyo, 2018; Lin, 2019), and the promotion of lifelong learning (Melnikova et al., 2017; Misra, 2018).

Alongside advantages for learners, the use of OER also provides opportunities for teaching staff and learning designers. The European Framework for the Digital Competence of Educators (Redecker, 2017) identifies one key competence for all educators as the ability to "effectively identify resources that best fit their learning objectives, learner group and teaching style, to structure the wealth of materials, establish connections and to modify, add on to and develop themselves digital resources to support their teaching" (p. 20). As well as building digital literacy skills (Bossu & Willems, 2017), another aspect of this is understanding open licences and the use of OER (Preradovic & Posavec, 2019; Weller, Jordan, DeVries, & Rolfe, 2018). As Bossu and Willems (2017, p. 22) assert, OER can "provide opportunities for collaboration, promote curriculum innovation and student led content development, as well as contribute to… teachers' much needed continuing professional development". In addition, cost efficiencies for course developers (King, Pegrum, & Forsey, 2018; Menon & Bhandigadi, 2018) should not be underestimated.

Educators developing OERu micro courses build new skills in wiki editing and writing for the web, using FOSS tools, finding openly licensed content, and adopting pedagogies embodying 'free-range learning'. Writers are pushed to consider the audience more than ever before, knowing that OERu learners are spread across six global regions; content needs to appeal to, and be clear to a global audience, many of whom are not native English speakers.

The OERu international network also demonstrates its potential by collaborating on content writing, assessment moderation, and idea generation, to ensure a meaningful experience for OERu learners. In practical terms, this means that educators and/or developers in New Zealand, for instance, may draft course content or an assessment which is then shared with OERu network colleagues in Africa, Canada, Scotland, and/or the United States for feedback. As well as

strengthening connections between collaborators and the OERu network in general, this also builds capability across the OERu community, and ensures robust moderation processes amongst experienced staff working in different contexts. As García-Holgado and García-Peñalvo (2018, para 7) emphasise, “people are not only end-users but also an important component of a learning ecosystem”, and this is certainly the case in the OERu.

Transnational collaboration enables us to consider intercultural dimensions of the learning experience and to integrate internationally relevant issues into our content (Caniglia et al., 2017). This also facilitates contribution to two of the United Nations Sustainable Development Goals (United Nations, n.d.), specifically Goal 4, ‘Quality Education’, and Goal 17, ‘Partnerships for the Goals’. With the UNESCO and International Council for Open and Distance Education (ICDE) Chair in Open Education Resource, Dr Wayne Mackintosh, Director of the OER Foundation based at Otago Polytechnic in New Zealand, we fully embrace the mission to connect people through “the fostering and sharing of ideas” and “building the knowledge and capabilities needed to ensure a better future for all” (New Zealand National Commission for UNESCO, 2019).

Conclusion

The OERu’s NGDLE experience suggests that the status quo for IT infrastructure in higher education institutions is neither the only way to do things, nor is it the best way. With the OERu unbound by historical decisions or conventions, it is able to pioneer new approaches. Driven by open principles and constrained resources, the OERu only needs to fulfil its clear vision: to build a rich, fit-for-purpose infrastructure for learners and OER collaborators alike, with the potential to scale to facilitate large numbers of learners distributed across the globe.

Implementing a FOSS end-to-end service gives the OERu a unique perspective and experience, when compared with organisations who may only implement the occasional FOSS component, in the midst of IT infrastructure dominated by proprietary commercial software that is costly and extremely restrictive by comparison.

The advantages of the OERu’s component-based NGDLE are both technological and pedagogical, for the benefit of both communities of learners and educators across the globe. It demonstrates both almost unbelievable cost-effectiveness and the ability to adapt rapidly to meet evolving learner needs, while gently immersing learners in precisely the digital environment which they need to gain confidence and virtuosity to thrive in furthering their education or as qualified professionals.

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