Systems Architectures

TU060

VLE Technology Review & Comparative Analysis of Smart Cloud-based VLE Offerings

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Declaration

I hereby declare that the work described in this report is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

Signed:

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2. VLE Technology Review

Introduction

This report examines current and future virtual learning environment (VLE) technologies which can help TU Dublin deliver the best possible remote learning experience for students.

Virtual classroom

The virtual classroom is perhaps the bedrock of remote learning in the context of the COVID-19 pandemic. It is a replacement (or surrogate) for in-person teaching. In typical implementations, students are authenticated in the VLE and then use a link taking them to a video conferencing service for a live lecture. But the nature of the classroom - online, mediated via webcam and microphone, processed on a server, and served to student devices - implicates several technologies. A live chat service for all students; the streaming and recording of the teacher's audio and webcam (or screen, or slides); and finally the automatic storage of broadcasts for retrieval within the VLE. Thus for students under time constraints (unable to attend class synchronously), or those with poor connections, a well-rounded virtual classroom implementation is key to their learning experience.

How does this work in the context of cloud computing? *BigBlueButton* is an open source conferencing system and a useful example of a virtual classroom architecture. It is the backbone of the *Bongo* web application which TU Dublin's current VLE provider, *Brightspace*, uses. Its documentation (BigBlueButton, 2021) sets out several architectural components. First is a "single page, responsive [HTML5] web application" which utilises *React.js* and *WebRTC* on the client side, while the server side of the app uses *Meteor.js* (client-server communication) and *MongoDB* (persists the state of all current meetings). From here, several other apps and services manage the video conference and integrate it with the VLE including *redis pubsub*, *redis db*, *bbb-web* (3rd-party integrations)*, FreeSWITCH* (voice conferencing), *Kurento Media Server* (webcams and screen sharing), as well as a service for converting presentations. (For example, *Microsoft Office* documents are converted into PDFs using *LibreOffice*, and then further converted into vector or raster images).

File hosting

According to surveyed teaching staff in *Jisc*'s annual report (Gribble & Sumpter 2020), a key function of the VLE is as a repository for teaching materials. Thus any cloud-based VLE should support common file formats for content including PDF, PPTX, and videos. While hosting files requires little more than a file server, doing so performatively and with good user experience present two challenges. Firstly, it may be necessary to host files using a content distribution network (CDN). This is where files are hosted on a "geographically distributed group of servers" (Cloudflare, 2021). Such a service provides greater availability and increased redundancy in the event of peak demand, high loads, or even denial of service attacks. Secondly, for good user experience: certain filetypes (e.g. PDF) may not always

display natively in the browser; often such files require direct downloads and separate apps (particularly on mobile), necessitating off-site navigation. Thus an inline viewer is needed to render these within the VLE. For example, the company behind *Brightspace* has a *Document Conversion Service* and its own viewer implementation called *d2l-file-viewer*

Learning analytics

Analytics play an important role in optimising the student VLE experience. For example, Alves, Miranda, & Morais (2017) point out that analytics can be used to track student interactions and find behaviour patterns. Specifically, they say that analytics has two primary tasks: "predicting students' learning success and providing proactive feedback". For example, this may help spot struggling students or forecast future results. Indeed, a University of Maryland study (Sclater et a.l, 2016, cited in Alves et al., 2017) showed that students with low grades "used the VLE 40% less than those with C grades or higher".

eThink (2020) goes further, saying that artificial intelligence can provide "personalised learning paths" in learning management systems. These AI-generated paths, based on "the past history of content interactions and pages read", could be "more suited to the individual than the ones designers could create in past systems" and provide positive reinforcement for continuous learning. In my opinion, however, this is better suited to MOOCs or corporate training rather than TU Dublin's blended learning approach during the pandemic. For one, a larger-than-usual repository of materials would be required so that an AI learning engine can select a subset of appropriate content per student. Indeed, when eThink (2020) discusses AI: it does so in the context of a business organisation LMS which can (via learning analytics) recommend content from external sources like Lynda.com and Skillsoft.

Assessments & interactive content

Another key part of a VLE's featureset. A VLE should provide a means to upload & grade student assessments. It may be necessary to link these assessments with other university systems (student records). Moreover, inline assessment or interactive activities can be useful; for example, Johnson (2019) argues the use of quizzes "can help [teachers] ensure [students are] absorbing the material". One technology, H5P, is a plugin for Brightspace (H5P, 2021) and other platforms enabling teachers to create interactive videos, quizzes, and games which can be included inline and integrated with a VLE's analytics and assessment tracking.

Conclusion

There are several VLE technologies which I have omitted for brevity. One is SCORM, "a set of technical standards for eLearning products" (SCORM, 2021). Others include the ability to schedule content (e.g. hide/show materials week by week, issue notifications for new content and deadlines); student portfolios; badges or certification; share or export functionality (e.g. to LinkedIn). Finally, perhaps the most important technology implicit in a VLE is the provision of a good mobile app.

3. Smart Cloud VLE Offering - Comparative Analysis

Introduction

In this analysis I examine four virtual learning environments (VLE) for delivering higher education remote teaching. After a description of each platform and its implementation and hosting requirements - making extensive use of the British Government Digital Service's (GDS) *Digital Marketplace* for comparing cloud offerings - I will briefly contrast and compare them under the categories of: learning & accessibility, ethics, and privacy & security. In doing so, I will critically assess each and finally make a recommendation.

Cloud Service Oriented Architecture

But first, let's discuss service oriented architecture (SOA). SOA is an architectural pattern where each service should use "common interface standards" (IBM Cloud Education, 2021a). A VLE with this quality makes it easier to integrate and reduces the need to "[redevelop] or duplicate existing functionality". Specifically, IBM says SOA-friendly services should "execute a complete, discrete business function" and provide loosely coupled interfaces so that there is less "dependency between applications", and in turn improve interoperability.

For example, consider the scenario of TU Dublin seeking alternate vendors for underlying services, such as video conferencing (the university uses Microsoft Teams in other contexts), rather than a default built-in service like the one provided in Brightspace. If the VLE is architected in an SOA way, this might make switching video conference providers easier.

Likewise if TU Dublin wishes to integrate other services (like authentication or SIS) with a VLE to populate enrolment data or fetch grades, SOA would help. Further, SOA architecture means that if the university switches VLE, updating endpoints would be relatively painless.

Thus a VLE that is both cloud and SOA-friendly should be deployable as a single discrete service with an exposed API which can be used by other university services. Optionally, for application development: constituent, underlying components/services should also have good API support for web services[1].

Providers

Moodle

Moodle is an open source learning management system (LMS) for higher education (Government Digital Service (UK), 2021a). GDS says that it integrates with HR, ERP, and CRM

[1] For the purposes of this analysis, we don't consider VLEs in terms of a microservices architecture for the university's overall IT system. As IBM points out (IBM Cloud Education, 2021b), SOA relates to "the way all web services in an organization talk to and integrate with each other" as opposed to microservices which are "application-specific". However, VLEs themselves might be internally designed with a microservices architecture ("a single application from many smaller, loosely coupled services"). This may provide f increased resilience: if one service goes down (like video hosting or conferencing), it doesn't affect other VLE services.

systems, and lauds it for its “integration and interoperability with other platforms”. Importantly, its cloud deployment model can be either private cloud or public cloud - which means organisations like TU Dublin can self-host in the cloud without relying on a 3rd-party service. (However, some companies - such as UK-based Synergy Learning, which GDS examines - do provide a fully managed service for deployment and development of Moodle). An important feature in their offering is the ability to provide a comprehensive backup and archive of Moodle data in order to switch platform/provider at a future date, which may suggest Moodle is more interoperable than other VLEs.

Most importantly, Moodle has an API and over 200 web services which “enable other systems to push and/or pull [data] from the [platform] and perform operations” (Government Digital Service (UK), 2021a). And because it’s open source, “the core code can be deployed as-is or customised to specific needs” such as “additional web services”, integrations, and community plugins.

Brightspace

Brightspace, which TU Dublins uses, is a fully-managed solution offered by Desire2Learn UK (D2L). Unlike Moodle, it cannot be self-hosted and deployed in a public cloud. (Organisations must use Brightspace’s managed cloud service). This may have benefits such as reducing IT staffing overhead in administering the VLE as well as increased reliability. (Brightspace, for example, claims it has 99.9% uptime). Added, the company claims it has “the most modern software architecture in our industry” and the platform makes internal use of microservices.

GDS (Government Digital Service (UK), 2021b) also describes it as an “extensible platform” which has “open REST-based APIs [...] with JSON as the data interchange format” - a key feature for supporting a service-oriented architecture. This allows for management of enrolment and grades which can be pushed directly to an SIS. Moreover, Brightspace says outside developers “can use whatever web development platform they are comfortable with to interact with these APIs”.

Like Moodle, it has all standard LMS and VLE functionality. However, it also boasts so-called advanced features it terms as Performance Plus (analytics) and Engagement Plus (a lecture capture and game-based learning engine). Further, it provides API access to its analytics data (a feature that Canvas also offers).

Lastly, Brightspace says it provides tools for exporting course content “in a standard, packaged format as well as grades and other specific elements of data.” Unlike the managed service provided for Moodle, however, it is less clear that backups and archives use a common standard which would help the university to switch LMS at a future date.

Blackboard

Blackboard Learn Ultra is another proprietary LMS. Like Brightspace, it has many standard features as well as a “robust integration framework using REST APIs and popular ed-tech

standards" and a claim of 99.9% uptime (Government Digital Service (UK), 2021c). Blackboard says its API is a "lightweight, flexible web service architecture without unnecessary overhead" that can integrate with an SIS, offering examples and tutorials on API integration. This includes a dedicated "Developer Portal" where REST apps are registered, integrations tracked, and credentials stored - along with an API testing environment.

Like Brightspace, it is hosted on AWS. Unlike Brightspace, GDS determines its cloud deployment model as public cloud (Blackboard can alternatively be self-hosted, so I take this to mean that, even under a managed-hosted Blackboard implementation, the university staff would have some form of direct access to infrastructure on AWS). Blackboard floats its onboarding and training process as a unique selling point (including for developers), thus it may offer better support for integration with the university's service-oriented IT infrastructure. Like Brightspace and Moodle, a managed-hosting version of Blackboard offers "data extraction" at end-of-contract - though it's not clear how easy migration is.

Canvas

Finally, like Moodle, Canvas is open source (Government Digital Service (UK), 2021d), with either self-hosting or AWS managed-hosting. But, unlike Moodle, its parent company is more explicitly commercial. Like Blackboard, it offers onboarding. However, its managed product offering has three tiers ("Standard, Enhanced, and Premium") and while a "Learning Consultant" for course design is part of onboarding, live developer support is not clearly signposted. But like all others Canvas offers an open REST (JSON) API with CRUD "for nearly every function within the Canvas VLE" along with SIS and authentication integration, and its API documentation is perhaps the most impressive of all options surveyed.

End-of-contract process is less clear, and Canvas ominously prefaces a description of this by saying: "in the unlikely event that a user chooses to leave Canvas". However, Canvas insists it has an "inherently open nature" in terms of migrating to other VLE providers.

Learning & Accessibility

Moodle pointedly supports question banks for creating assessments and allows the tracking of "scores and completion rates" (Government Digital Service (UK), 2021a). Interestingly though, GDS says both Blackboard and Brightspace support "drag & drop course creation" - a feature lacking in Moodle. Further, D2L say they employ "a blind screen reader user in the role of accessibility tester, test strategist and consultant" and use several accessibility standards and internal processes to make the platform and various tools more accessible. But Brightspace may have issues with interoperability of course content created under the SCORM standard as attested to by online discussions and special import instructions.

An interesting feature of Canvas' API is the ability to set up announcements, assignments, and quizzes - which has useful implications for repeat course runs. (Students can also submit assignments by API!).

Moodle, Blackboard, and Canvas all offer UI customisation to match university branding - a feature notably absent (or at least underdeveloped) in Brightspace. All providers support mobile devices with a responsive design and similar mobile and desktop experiences. However, one article which discusses a university that switched from Canvas to Blackboard last year notably suggests that Blackboard "struggled on mobile devices" (Peters, 2021). PC Mag, which provides an extensive review of all four offerings rates Canvas and Moodle with scores of 4.5, while Blackboard and Brightspace each receive 4.0 (Fenton, 2018).[2]

Ethics

All LMS's claim detailed analytics and features like "learning pathways". However, Brightspace seems to have the greatest analytics capability; PC Mag (Fenton, 2017) draws attention to its Engagement Plus service "which features the company's predictive and performance analytics, including Brightspace Insights, LeaP, and the Student Success System". Meanwhile, National Forum (2019) says Brightspace's "predictive analytics help lecturers identify at risk students", providing "all details are at the lecturer's fingertips".

But this begs several questions. Yes: analytics may allow identification of struggling students or those unlikely to complete courses - but what should be done with this information? Should they intervene directly (speak to the student) or would this impinge upon their privacy? Alternatively, would time spent on such unprompted interventions be unfair to other students in terms of educators redirecting contact time? Lastly, I wonder if such analytics could prejudice educators or feed implicit bias in grading assessment. (For example, if an educator is fully aware that a student hasn't engaged with course materials throughout a semester, would this influence the amount of marks awarded?).

Privacy & Security

Since Moodle is open source, this presents security challenges. For example, attackers might scrutinise the source code and find vulnerabilities. Added, if a university customises its installation (and adds plugins), upgrading to new Moodle versions may present challenges. This in turn may create ongoing security debt with the university exposed to legacy vulnerabilities already patched in newer versions. As with all other providers, Moodle supports authentication managed via identity federation with providers like Office 365 along with extension documentation on integration. Interestingly three of the VLS options (including managed hosting partners) are not certified according to several industry security standards listed by GDS. Brightspace, however, proves the exception with numerous certifications and conformity with many standards according to GDS (Government Digital Service (UK), 2021b) and its website: "We're the only major LMS provider with an ISO 27001 certification." Both Blackboard and Brightspace are hosted on AWS, which has an Irish data centre, which may have beneficial implications for data processing and privacy.

[2] Though it should be pointed out these reviews were carried out in 2017, and Blackboard have since relaunched their core offering with a resign known as Blackboard Ultra - though this is available as SaaS only.

Conclusion

Each smart cloud-based VLE offering boasts all relevant features and appears fully compatible with service-oriented architecture. Notably, however, Brightspace lacks a self-hosted option; nor does it support alternate video conferencing providers (which Moodle and Blackboard both seem to allow). Though it provides an extensively documented API (albeit perhaps less readable and developer-friendly than Blackboard or Canvas), its GDS description also suggests it is slightly less interoperable and friendly to migration.

Moodle is clearly the most customisable; while Brightspace is both the least customisable option yet perhaps easiest to configure. By contrast, Blackboard is the most "robust, mature product" (Capterra LMS, 2016) - whereas Canvas seems to have the most interesting learning design features and an API which may support novel integrations. Perhaps most importantly, Brightspace boasts the best security. Thus we can conclude that, during the immediate future at least (and in part because it may be less friendly for migration), no other option presents a compelling reason for TU Dublin to switch VLE at this time.

4. Reflection on self-hosting via AWS

I found this process incredibly simple and easy. (It took me about 10 minutes all-in-all - whereas writing the various reports and the presentation took more than a day each!).

One option I did consider was hosting my assignment via web app hosted on Elastic Beanstalk. (AWS has a tutorial for this which I went through and used to deploy the containerised Docker image which I created during the Week 8 lab). However, deploying a full web app (for a simple document and presentation) seemed a bit overkill - so I opted to use AWS's serverless Amplify service to host a simple static web app.

I used create-react-app to build an app within which I could statically host my assignment files. From there, I follow AWS's tutorial on how to host a static website.

I did encounter several unusual difficulties: AWS's Amplify server did not work in my regular browser. (Opening it in an incognito tab fixed this issue). Moreover, my installation of npm and npx appeared corrupt and I couldn't create a new create-react-app. However, I was able to copy a skeleton React App I created a few months ago and repurpose this to host the two files.

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