A Multivocal Literature Review on the use of DevOps for e-learning systems

Mary Sánchez-Gordón
Østfold University College
Halden 1757
Norway
mary.sanchez-gordon@hiof.no

Ricardo Colomo-Palacios
Østfold University College
Halden 1757
Norway
ricardo.colomo-palacios@hiof.no

ABSTRACT

DevOps is an approach to reduce software development times by integrating a set of tools in order to get a better and automated transition towards production. DevOps is highly connected to tools and to Cloud Computing. On the other hand, e-learning tools are also evolving towards the cloud. In this scenario, the connection of this two research fields seems to be promising. However, to the best of authors' knowledge the interaction of both has not been studied in deep. To bridge this gap, in this paper, a multivocal literature review is presented. By means of this systematic approach, authors analyze scientific and professional literature on the topic. Results reveal a nascent but still modest interest in DevOps in e-learning solutions. Authors believe that the increasing adoption of cloud e-learning solutions and the increasing pressure to deploy new versions of software with boost the interest in this research field.

CCS CONCEPTS

• **Software and its engineering → Collaboration in software development**; • Applied computing → E-learning

KEYWORDS

E-learning systems, Learning management systems, DevOps, Multivocal literature review

1 INTRODUCTION

The use of Information and Communications Technology (ICT) has had an important impact in human activities, including education and learning. As a consequence of this, a new field called e-learning has impacted the discipline in a deep way. The e-learning is a form of distance learning that is completely virtualized through an electronic channel (medium), like the Internet [16]. According to the European commission e-learning is described as the use of Internet and new multimedia technologies to advance the quality of learning by providing access to resources and services, as well as enabling remote exchange and collaboration [13].

One type of e-learning system that has become very popular among universities is a learning management system (LMS) [11]. However, the adoption of LMSs is not limited to learning institutions such as universities and schools [22]. Corporations and government bodies also have been implementing such platforms to promote the employees' education and training [22]. Indeed, the use of technology is ubiquitous in the educational system in most developed countries [3].

On the other hand, the main architectures that are used for developing an e-learning system are cloud computing, service-oriented architecture, distributed computing or event driven architecture [23]. By providing many applications and services in the cloud to the learners and teachers which can be used for educational purposes cloud computing allows greater flexibility and mobility in the use of resources for teaching purposes [9]. According to [23], an ideal architecture would combine all of these architectures' advantages and integrate them in cloud environment.

In particular, cloud computing usability in education is very wide and it is recognized by many educational institutions around the world [9]. Cloud computing provides dynamically scalable infrastructure supplying computation, storage and communication capabilities as services it can provide tremendous values to e-learning [14]. The broad range of service delivery models are: IaaS (infrastructure as a service), PaaS (platforms, operating systems, execution environments as a service), SaaS (software applications delivered as a service), and BPaaS (business processes offered as a service) [2]. However, the characteristics of an e-learning system in cloud may differ depending on the type of cloud architecture: public, private or hybrid [23]. Moreover, from this point the philosophy and the implementation of the system take different turns [23].

In this scenario, a DevOps approach makes sense to ensure consistency for all stages of development, quality assurance, and operations [1]. DevOps efficiently integrates development, delivery, and operations, thus facilitating a lean, fluid connection of these traditionally separated silos [6]. Despite the term DevOps is vaguely defined and loosely used in the software engineering community [21] as well as there is no standard definition for DevOps [12], literature acknowledged advantage of implementing DevOps [4, 6, 20]. In other words, "shorten release cycles" such that each feature developed is deployed as soon as it is ready, therefore producing rapid feedback to the developers on the ability for system administrators to deploy, configure, and operate the new software [1]. The DevOps term represents also the need to align the development of software and the deployment of that software into production [5]. Moreover, according to [7], DevOps recognizes that the integration between software development and its operational deployment needs to be a continuous one. That

means continuous integration, continuous deployment, continuous delivery, continuous verification/testing, continuous security and continuous compliance in development to get continuous use, continuous trust and continuous run-time monitoring in operations [7]. In this sense, tools are mandatory in automating DevOps [6] and choosing the right tools for an environment is important when you move to DevOps as a way also to embrace microservices architectures [17].

Overall, there is a remarkable interest in DevOps from practitioners [12, 21] and a growing attention from researchers in the last years, especially since 2014 [21]. However, and in spite of the importance of e-learning systems on the one hand, and the other, the nascent significance of DevOps, to the best of authors' knowledge, there is not a secondary study on the use of DevOps for e-learning systems. Giving that DevOps is a term deeply related to professional matters, there is a need to work on the topic using a tool like multivocal literature review. This study attempts to bridge the gap between professional and scientific literature. By this mean, we examine the influence of DevOps on e-learning systems and identify opportunities for future research.

The structure of the paper is as follows. Section 2 presents the design of this MLR while section 3 reports on the results of the MLR. Finally, section 4 summarizes a conclusion and further research.

2 METHOD

The main purpose of this study is to observe, document and analyze the state of the art related to the use of DevOps for e-learning systems. Thus, the goal is to find out the recent trends and directions in this topic, and to identify opportunities for future research, from the point of view of researchers and practitioners. To do that, a multivocal literature review (MLR) was conducted due to it is defined as all accessible literature on a topic [19]. Thus, a MLR consists of a careful study of academic literature and grey literature, where the last one includes but is not limited to: blogs, post, white papers and articles [8]. As far as the authors know, this is the first MLR on this combined topic although it is not the first one for DevOps (e.g. [18]).

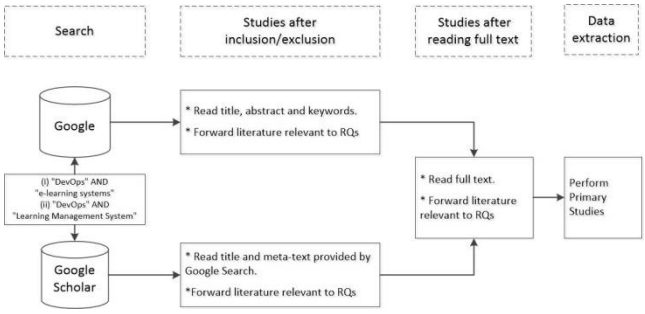


Figure 1: An overview of the search process.

In the remaining of this section, authors outline the study protocol that describes the systematic way we found the literature used in this study (see Figure 1). The protocol includes the databases used in the search, the search strategy, the inclusion and exclusion criteria, and the data extraction.

2.1 Research Questions

In order to achieve the goal of this study, two research questions were formulated:

RQ1: How has DevOps evolved in the e-learning systems area?

RQ2: What is the use of DevOps for e-learning systems?

In this MLR, two researchers were involved in the selection process: the first author of this paper carried out the selection process and the second author reviewed the process, verified the outcomes and support the resolution of doubts. Moreover, we used the spreadsheet tool MS Excel to manage all the phases of this process and to store the information collected about the searches.

2.2 Search

Two sets of keywords were identified: (i) Scoping of the search, "DevOps" and (ii) Search terms directly related to the intervention, i.e. "e-learning system" and "learning management system". Therefore, the search strings used for each database was (i) *"DevOps" and "e-learning system"*, and (ii) *"DevOps" and "learning management system"*. The search was performed on two databases search engines, Google Scholar and Google. For this study, both of them were estimated as enough because they cover all major publisher venues (e.g. Elsevier ScienceDirect, Springer, ACM and IEEE). In the first one, we searched the academic literature and the second one we searched the grey literature.

This MLR was performed by May 2018. The search period was from January 2014 to May 2018 because, as mentioned before, DevOps has gained relevance since 2014 [21]. It is also worth noting that when using the Google's regular search engine, we utilized a relevance ranking approach (Google's PageRank algorithm) as did Garousi and Mäntylä [8] to restrict the search space in this type of secondary studies. For instance, when the search string *"DevOps" and "learning management system"* was applied to Google, 11,400 results were found. But as by simple observations, relevant results usually only appear in the first few pages only the first several pages were checked (at least 10) and only continued further if needed, that means we proceeded to the (n + 1)th page only if the results in the nth page still looked relevant.

Table 1 shows the number of search results per database. As one can see, we found 232 publications in the initial search.

Table 1: Summary of search results for primary study.

Studies	Google	Google Scholar	Total
Studies retrieved	200	32	**232**
Studies after inclusion/exclusion	33	14	**47**
Studies after reading full text	22	3	**25**

2.3 Study Selection

We excluded articles based on titles, abstracts and keywords, as well as full-text reading. The application of inclusion and exclusion criteria to titles, abstracts and keywords was conducted by the first author. The following inclusion criteria were applied:

- Studies present the use of DevOps in e-learning systems or LMS.
- Studies are in the field of software engineering.
- Studies were published online in the period 2014 to 2018 (this study was conducted during May).

The following criteria state when a study was excluded:

- Studies not presented in English.
- Studies not accessible in full-text.
- Studies that are duplicates of other studies.

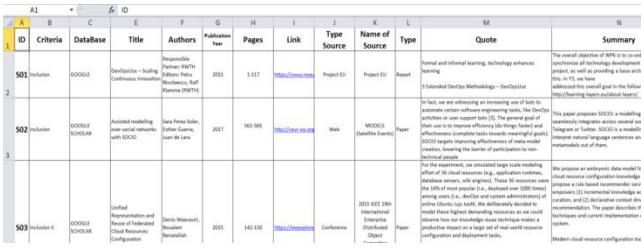
On one hand, if a publication was clearly out of the inclusion criteria, it was classified as non-selected paper (NS) and it was not included in the following phases of the selection process. On the other hand, if a publication accomplished with the inclusion criteria, the publication was classified as possible selected paper (PS) and was included in the next phase of the process. When in doubt, we were inclusive taking the publication to full-text reading, i.e. the publication was classified as possible selected papers (PS).

After that, publications classified as possible selected papers (PS) were thoroughly analyzed by reading the full text. In this way, we attempted to ensure that the publication certainly contains relevant information for this study. At this point, non-relevant publications were classified as non-selected paper (NS) and relevant publications were classified as selected paper (S). Moreover, during full-text reading it became obvious that further publications should be removed because they were not in the scope based on the inclusion and exclusion criteria.

The primary studies are the union of the scientific and grey primary studies. At the end of the process, the list of publications was formed by 25 publications (see Table 1). Those publications defined the set of primary studies of this MLR. Finally, those primary studies were analyzed in order to get the needed information to answer the research questions.

2.4 Data Extraction

At this stage, all the primary studies were read completely in order to collect all the needed information and ensure that the data are accurate. The bibliographic details for all the 25 primary studies are available in appendix A and referred in the form of [S01],…, [S25] in this paper. To extract data from the identified primary studies, we developed the following template: (i) Database, (ii) Title of the publication, (iii) Set of names of the authors, (iv) Publication Year, (v) Pages, (vi) Link, (vii) Classification according to source and publication types (see Table 2), (viii) Quote (ix) Summary. Figure 2 shows a snapshot of the spreadsheet in which we stored the data.



ID	Criteria	DataBase	Title	Authors	Publication Year	Pages	Link	Type Source	Name of Source	Type	Quote	Summary
S01	Inclusion	GOOGLE	DevOpsUse – Scaling Continuous Innovation	Responsible Partner: RWTH Editors: Petru Nicolaescu, Ralf Klamma (RWTH)	2015	1-117	https://www.rese	Project EU	Project EU	Report	Formal and informal learning, technology enhances learning 3 Extended DevOps Methodology – DevOpsUse	The overall objective of WP6 is to co-ord synchronise all technology development project, as well as providing a base arch this. In Y3, we have addressed this overall goal in the follow http://learning-layers.eu/about-layers/
S02	Inclusion	GOOGLE SCHOLAR	Assisted modelling over social networks with SOCIO	Sara Perez-Soler, Esther Guerra, Juan de Lara	2017	565-985	http://ceur-ws.org	Web	MODELS (Satellite Events)	Paper	In fact, we are witnessing an increasing use of bots to automate certain software engineering tasks, like DevOps activities or user support bots [3]. The general goal of their use is to improve efficiency (do things faster) and effectiveness (complete tasks towards meaningful goals). SOCIO targets improving effectiveness of meta-model creation, lowering the barrier of participation to non-technical people.	This paper proposes SOCIO: a modelling seamlessly integrates across several so Telegram or Twitter. SOCIO is a modelli interpret natural language sentences an metamodels out of them.
S03	Inclusion II	GOOGLE SCHOLAR	Unified Representation and Reuse of Federated Cloud Resources Configuration	Denis Weerasiri, Boualem Benatallah	2015	142-150	https://ieeexplore	Conference	2015 IEEE 19th International Enterprise Distributed Object	Paper	For the experiment, we simulated large scale modeling effort of 36 cloud resources (e.g., application runtimes, database servers, wiki engines). These 36 resources were the 34% of most popular (i.e., deployed over 1000 times) among users (i.e., devOps and system administrators) of online Ubuntu (ub-tool). We deliberately decided to model these highest demanding resources as we could observe how our knowledge reuse technique makes a productive impact on a large set of real-world resource configuration and deployment tasks.	We propose an ontonymic data-model fo cloud resource configuration knowledge propose a rule based recommender serv empowers (1) incremental knowledge ac curation, and (2) declarative context dri recommendation. The paper describes th techniques and current implementation system. Modern cloud resource configuration to

Figure 2: A snapshot of the spreadsheet.

3 RESULTS

3.1 Evolution of DevOps in the E-learning Systems Area (RQ1)

Figure 3 shows the percentage of primary studies retrieved from the scientific and grey literature, which are included in this MLR. Only 12% of the primary studies (3) come from the scientific literature, while 88% of the primary studies (22) come from the grey literature. Therefore, this topic is an emerging research scope.

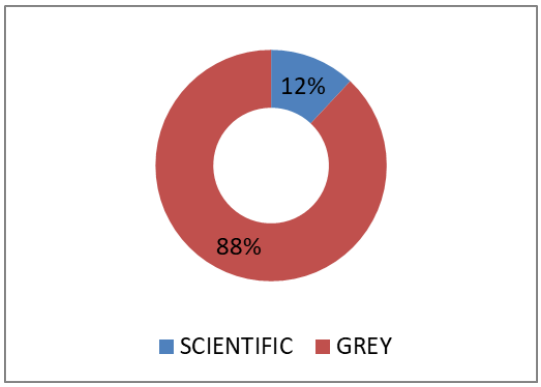


Figure 3: Number of included publications during the study selection process.

Figure 4 shows the number of primary studies identified regarding their year of publication. As one can see, year of publication is not available (N/A) in a group of publications (7 out of 25). That group is made up of websites, which describe services or products of companies that claim to be using DevOps. Moreover, a high number of publications retrieved (14 out of 25) were published since 2017. However, it is worth mention that 7 of them are job ads, this allows us to see that there is a growing but limited interest in DevOps in the e-learning industry.

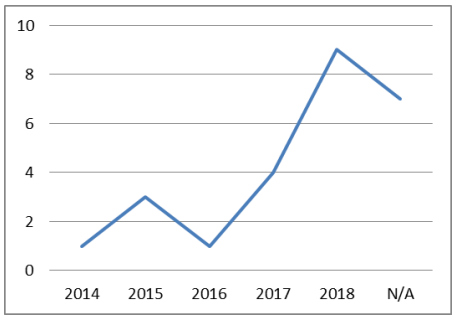


Figure 4: Number of primary studies by year (No Available, N/A).

3.2 The use of DevOps for E-learning Systems (RQ2)

In this study, all the publications that are related to DevOps and e-learning system were included. Table 2 provides an overview of the distribution of publications between source and publication type.

Table 2: Primary studies' source and publication type.

Source Type	Publication Type	#	%	Studies
EU Project	Report	1	4	[S01]
Conference	Paper	6	24	[S02] – [S07]
Web	Job ads	8	32	[S08] – [S15]
	Service/Product	10	40	[S16] – [S25]
Total		**25**	**100**	

Looking at the specific publication type, it was clear that the EU Project was the most significant research effort to use DevOps in this context. On the other hand, the job ads give us a good idea about the real demands of DevOps role in the e-learning industry. Overall, this indicates that there are services and products related to e-learning systems that use DevOps.

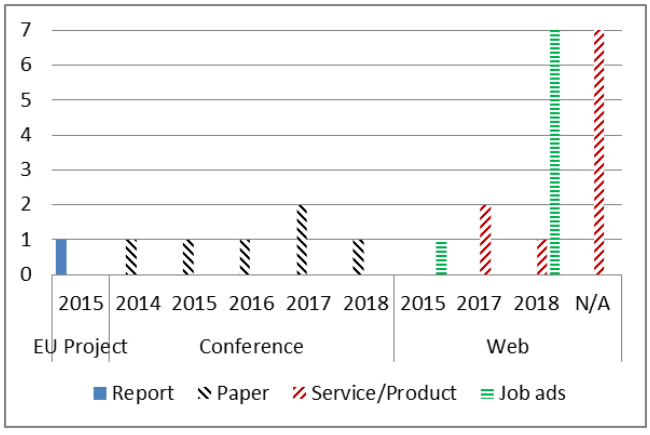


Figure 5: Number of primary studies regarding the source and publication type.

Figure 5 depicts the data of Table 2 by year. The EU Project is a report [S01] published in 2015. It developed technologies that support informal learning in the workplace. That project was focused on Small and Medium sized Enterprises (SMEs), and created a DevOpsUse approach based on DevOps in order to achieve its goal.

All 6 papers, [S02] – [S07], were presented in different Conferences, one per year (2014 to 2018), except in 2017, when there were 2 paper published. Half of all papers, [S02] – [S04], were found in Google Scholar while the remaining papers were found in Google. Concerning the use of DevOps, [S06] and [S07] stated that they use DevOps tools, the first one present an architecture that provides a generic solution for the autonomous runtime management of heterogeneous cloud systems. The second one describes an architecture based on cloud services that simplifies the process of managing an online course, from delivering on-demand fully customized remote laboratories to communication automation for student engagement and feedback gathering. Moreover, [S02], [S03], [S04] and [S05] suggest the use of DevOps in this area but it is not clear if they are using DevOps. [S02] presents a modelling bot called "SOCIO" that can interpret natural language sentences and create meta-models out of them. As an example, the authors show the processing of several natural language messages used to build a meta-model for e-learning systems. In [S03], a data-model for representing cloud resource configuration knowledge artifacts is proposed and an e-learning service is presented like an application scenario. The authors of [S04] propose to make intelligent agents on platform IBM Bluemix with IBM Watson technology. These agents in the form of chatbots have to automate the interaction between the student and the teacher within the frames of LMS Moodle. [S05] shows that the combination of educational resources in virtual containers with free and open distribution channels can be an important tool for the distribution of an open educational resources (OERs) approach in science, technology, engineering, arts and mathematics STEAM areas.

Additionally, there are two groups in the category "services or products". The first group is composed by 3 blogs which make reference to DevOps in the context of e-learning as follow: (i) an announcement of a talk about Joomla centric DevOps [S16], (ii) the migration of a massive LMS to AWS on behalf of Macmillan Publishing [S17] and (iii) The existence of DevOps professionals in WordPress development agencies to build a software as a service LMS [S18] The second group, as mentioned before, is labeled as not available (N/A) because it is composed of companies' websites. 3 of them ([S20], [S21] and [S22]) are mentioning DevOps but they do not specify how they are using it. At the same time, the others 4 companies claim to be using a DevOps approach as follow. In [S24], Microsoft Azure in Education is presented but the details about DevOps are given in the Microsoft Azure website, https://azure.microsoft.com/en-us/solutions/devops/. In this case, DevOps brings together people, processes, and technology, automating software delivery to provide continuous value to users. Thus, Azure DevOps solutions are expected to deliver software faster and more reliably. The solutions are based on a continuous integration and continuous

deployment (CI/CD) pipeline that pushes each of the changes automatically to Azure app services. That allows one to deliver value faster to customers. By combining continuous integration and infrastructure as code (IaC) is expected to achieve identical deployments and the confidence one needs to manually deploy to production at any time. In turn, continuous delivery ensures that code and infrastructure are always in a production-deployable state. Moreover, Azure Application Insights provides actionable insights through application performance management and instant analytics. In order to ensure compliance, one can manage provisioned infrastructure and application using DevOps tools such as Chef Automate or Azure Policy.

Furthermore, [S23] is applied DevOps as continuous integration practice that requires developers to integrate code into a shared repository at regular intervals. That concept was meant to remove the problem of finding later occurrence of issues in the build lifecycle, so that continuous integration requires the developers to have frequent builds. There, the common practice is that whenever a code commit occurs, a build should be triggered.

[S25] employs also DevOps as software delivery approach that focuses on speed and efficiency without sacrificing stability and quality. For its customers, this approach yields significant improvements in speed, capacity, and cost. Finally, [S19] offers custom development for LMS integration and customization. This company is providing a DevOps support from server management and monitoring, to rolling out frequent updates and deployments. According to its website, DevOps support team gives its customers more freedom and security to build and grow with confidence.

3.4 Limitations of the Study

Given that each publication was reviewed by a single author, this could be a major threat to the validity of this MLR because of possible human errors or subjectivity opinions. To reduce the influence of that threat, we decided to develop the review protocol following the guidelines proposed by [15] and to perform each selection process based on a test-retest approach. Moreover, one expert researcher reviewed the work carried out during all the complete procedure of this MLR. Another limitation is the inclusion of English-only publications because relevant studies in other languages could be missed out. Finally, this research is based on multivocal literature, and most of the material has not been subject to the rigorous peer-review academic research usually is.

4 CONCLUSIONS AND FUTURE WORKS

In summary, we have performed a MLR on the use of DevOps for e-learning systems. We used Google Scholar and Google Search to find literature and after applying the inclusion and exclusion criteria, 25 publications were identified as relevant to this research scope. One of them is a research project that created an approach based on DevOps while 2 more were academic research papers which stated they are using DevOps tools. There are also 4 papers presented in Conferences that suggest the use of DevOps but it is not clear how they use DevOps. The remaining 19 publications consisted of white papers, blogs, job ads and articles. Despite the small number of publications available in the literature, it is expected that the results give us a global view at the topic because the review is using a variety of literature which includes the voices and opinions of academics, practitioners, independent researchers, development firms and others with experience [19].

In this MLR, the academic studies reveal little interest in this topic while the e-learning industry evidences an increasing but limited interest in the use of DevOps. Therefore, the use of DevOps should be investigated in detail due to its potential impact on the e-learning industry [10]. In this sense, it would be interesting to conduct research not only in DevOps tools but also in other aspects [21] such as cultural —values and principles—, methods and practices —including continuous practices.

A PRIMARY STUDIES

This appendix presents the list of primary studies.

A.1 EU Project

[S01] Klamma, R., Koren, I., Nicolaescu, P., Renzel, D., Kravcik, M., Shahriari, M., Derntl, M., Peffer, G. and Elferink, R. 2015. *DevOpsUse – Scaling Continuous Innovation*. Technical Report #Report 4 (D6.3).

A.2 Conference

[S02] Perez-Soler, S. and Guerra, E. 2017. Assisted modelling over social networks with SOCIO. *MODELS (Satellite Events)*. (2017), 1–5.

[S03] Weerasiri, D. and Benatallah, B. 2015. Unified Representation and Reuse of Federated Cloud Resources Configuration Knowledge. *2015 IEEE 19th International Enterprise Distributed Object Computing Conference* (Sep. 2015), 142–150.

[S04] Nenkov, N., Dimitrov, G., Dyachenko, Y. and Koeva, K. 2016. Artificial intelligence technologies for personnel learning management systems. *2016 IEEE 8th International Conference on Intelligent Systems (IS)* (Sep. 2016), 189–195.

[S05] Burgos, D. and Corbí, A. 2017. STEAM Subjects Enhanced through Virtual Containers for OER. (Dubai, 2017), 2–12.

[S06] Bruneliere, H., Al-Shara, Z., Alvares, F., Lejeune, J. and Ledoux, T. 2018. A Model-based Architecture for Autonomic and Heterogeneous Cloud Systems. (Funchal, Portugal, 2018), 201/212.

[S07] Moltó, G. and Caballer, M. 2014. On using the cloud to support online courses. *2014 IEEE Frontiers in Education Conference (FIE) Proceedings* (Oct. 2014), 1–9.

A.3 Web

[S08] Hiring for DevOps Consultant(Contract to hire) in Noida, for Exp. 4 - 5 yrs: *https://www.naukri.com/job-listings-DevOps-Consultant-Contract-to-hire-Forstaffing-Executive-Search-Firm-Noida-4-to-5-years-250518500053.*

[S09] Job opening: DevOps Engineer at Epignosis: *https://epignosis.workable.com/j/F780D8C510.*

[S10] Expertus - DevOps Engineer (5-10 yrs), Chennai, DevOps,AWS,Cloud,Ruby on Rails, Tech IT Jobs - hirist.com: *https://www.hirist.com/j/expertus-devops-engineer-5-10-yrs-208313.html.*

[S11] (4) Senior DevOps Engineer - AWS, Docker, Jenkins | Technology Navigators, Inc. | LinkedIn: *https://www.linkedin.com/jobs/view/senior-devops-engineer-aws-docker-jenkins-at-technology-navigators-inc-702947838/.*

[S12] Remote Verso is Hiring at Verso Learning: *https://remoteok.io/remote-jobs/9282-remote-verso-is-hiring-verso-learning.*

[S13] Linux Systems Administrator, Brighton: *https://stratospherec.com/jobs/linux-systems-administrator-brighton/143-1/.*

[S14] Mid-level Linux Systems Administrator Job in Sussex, ENG at Stratospherec: *https://www.ziprecruiter.com/c/Stratospherec/Job/Mid-level-Linux-Systems-Administrator/-in-Sussex,GBR?ojob=9567a867ccc555cae45a1bc09d892639.*

[S15] Junior Linux Systems Administrator Job in Sussex, ENG at *Stratospherec: https://www.ziprecruiter.com/c/Stratospherec/Job/Junior-Linux-Systems-Administrator/-in-Sussex,GBR?ojob=0cccefd6fee258e44571e9dbd07aee33*.

[S16] Talking about DevOps at Joomla Day UK 2017 - SSOFB - Web Development with Open Source in Aberdeen, Scotland: *http://ssofb.co.uk/news/talking-about-devops-at-joomla-day-uk-2017*.

[S17] DEVOPS: *https://www.reluscloud.com/devops/*.

[S18] How Much Does It Cost To Build A WordPress LMS? 2018. *https://elearningindustry.com/wordpress-lms-cost-build*.

[S19] 42 Lines - Custom Learning Software: *https://www.42lines.net/*.

[S20] Software Development | Euvic Group: *https://euvic.com/it-services/software-development*.

[S21] Media. ValueLabs: *https://www.valuelabs.com/industries/media/*.

[S22] Verso - Home: *https://verso.digital/*.

[S23] KnightWorks Consulting, Inc. | KnightWorks Consulting was founded in 2000 as an IT consulting, hosting, and application design firm: *http://knightworkshosting.com/*.

[S24] Microsoft Microsoft Cloud Profitability Scenarios: *https://assets.microsoft.com/de-ch/microsoft-cloud-profitability-scenarios-overview.pdf*.

[S25] Services | CTEC: *http://www.ctec-corp.com/services#enterprise-app*.

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