Mitigating the Digital Divide for Distance Learning Students in Developing Countries

Conference Paper · September 2015

CITATION
1

READS
338

3 authors:

Christine Spiteri
Middlesex University Malta
2 PUBLICATIONS **2** CITATIONS
SEE PROFILE

Clifford De Raffaele
Middlesex University Malta
29 PUBLICATIONS **127** CITATIONS
SEE PROFILE

Serengul Smith
Middlesex University, UK
26 PUBLICATIONS **164** CITATIONS
SEE PROFILE

Mitigating the Digital Divide for Distance Learning Students in Developing Countries

Christine Spiteri, Middlesex University, Malta, christinespiteri15@gmail.com
Clifford De Raffaele, Middlesex University, Malta, cderaffaele@ieee.org
Serengul Smith, Middlesex University, London, s.smith@mdx.ac.uk

Abstract

Purpose – This paper will focus on the limitations distance learning students encounter when they are required to access virtual learning environments (VLEs) from developing countries. Ideally, every student accessing a VLE should share the same experience regardless of their geographical location or broadband connectivity strength. Currently, the main limitation is the ability of information systems to adapt to the users depending on their technological platform, broadband quality and geographical location.

Design/methodology/approach – The aim of this research paper is to work towards optimising the use of information systems within distance learning to mitigate the current elements of the digital divide. Firstly, we will be introducing the digital divide and its implications on distance learning students. Secondly, we will be considering and criticizing current delivery of VLEs and assessing the current restraints based on broadband standards, geographical location and device compatibility. Finally, based on these findings we will amalgamate all insight gained in order to come up with a viable solution.

Findings – The findings of this paper will present a number of alterations undertaken at both client and server side which can augment the student experience in learning via virtual environments.

Research limitations/implications – Based on the proposed findings, the paper presents a solution which can assist in mitigating the digital divide for students undertaking technologically enabled distance learning.

Practical implications – This solution proposed is based on the hurdling of previously identified impediments within literature. Thus, the solutions highlighted in the paper aim at enhancing the student's virtual learning experience when using online platforms.

Originality/Value – The technologies adopted within the paper address the various constraints presented by telecommunication systems within developing countries by customising the manner in which virtual learning environments are employed. Making further use of novel technologies being adopted for educational aspects, the paper presents a unique solution to lessen the digital divide experienced between students utilizing information systems for learning within dissimilar infrastructures.

Keywords (3-5): virtual learning environment; digital divide; distance learning.

Research type: research paper

Introduction

The unequal access to information systems for distance learning students has been studied intensively over past years through different demographics and metrics which are resulting in different types and stages of digital divide. Following the wide study incorporated within this subject, it is known that the digital divide concept has been continuously progressed and shifted along the years; moving from digital have versus have-nots towards a more social and intellectual inequality.

Justification of the expanding gap between the digital have and have-nots has been analysed in detail through the consideration of a number of aspects such as lack of English knowledge, computer literacy, digital technology and unsuitable electronic infrastructure (Jones and Sallis, 2002). Following the emphasis on physical access, research is now moving towards analysing additional demographics including age, gender, institutional (Chinn and Fairlie, 2006), intellectual (Belanger and Carter, 2010), social, economic (Montagnier and Wirthmann, 2011) and cultural aspects (Tingoy and Gulluoglu, 2012). This amalgamates with results through other analytical publications including van Deursen, Helsper and Eynon (2014), and Pearce and Rice (2013) when looking into multidimensional concepts of the digital divide which consider personal attributes such as; attitude, motivation and mobile skills. Furthermore, information and network societies are experiencing gaps which are also caused by political issues (van Dijk and Hacker, 2003), however a framework has not yet been proposed in order to establish a common digital society. Van Dijk and Jan (2006) extensively criticize the lack of qualitative and dynamic research that has been done on this subject. The modern digital divide is not a question of whether distance learning students possess the right technology at hand, but the issue is more intrinsically revolved around new technology being constantly introduced which in turn causes a new form of divide.

Theoretical background

Over the years, a lot of interest has been shown on this subject and efforts were made to study the digital divide mathematically, however such measurement and analysis are definitely a complex and multidimensional task which require a lot of resources and critical thinking. Kyriakidou, Michalakelis and Sphicopoulos (2011) have done this aiming to analyse European countries' rate of broadband adoption. By formulating the relative penetration of each country considered, the digital divide gap is studied and estimates were made in regards to broadband convergence. Within this context, the discussed relative penetration was referring to different rates of broadband diffusion, which is still continuously increasing. A more elaborate and intensive research had been previously conducted to propose a model for measuring the digital divide within countries, by assigning a synthetic index of digitalization (Corrocher and Ordanini, 2002). Research on other developing countries has also been conducted with the aim of examining the gender perspectives on the digital divide within the IT domain (Kvasny et al., 2008). One of the main findings suggests that amongst the technical and social barriers that graduates experience, is the need of more advanced training and IT resources for both students and academics.

Penetration of broadband services and its infrastructure is seen as a key in developing and providing foundation of any information society. Within the educational sector, institutions are required to strengthen and utilize technology in teaching and learning processes through the enhancement of network infrastructures (Sanders, 2011). In his research, Falch (2007) compiles a set of factors which affect this and identifies the importance of policy measures to stimulate growth in this domain. A varied group of factors have been considered including effects on content, infrastructure, demand, supply, governments and education. This study highlights that two levels of competition (different types of infrastructures and different operators using the same type) form an important parameter towards equal penetration of broadband services. It has been noted however

that once the right infrastructure has been put in place, it seems that the issue shifts towards a higher focus on the demand side. This has lead Falch (2007) to conclude that, apart from technical and economic parameters, successful implementation of broadband also depends on the kind of public policy measures taken to stimulate the demand. Two methods of achieving such measures are specified to be through upgrades of information technology skills and content development.

Basing their research on the historic evolution of the digital divide across European states, additional studies have been made and different analysis interpreted in order to present a theoretical conclusion of the digital divide status. Such studies on digital gaps in regional dimensions conclude that there is still a lot to be done in order to reduce such imbalances in European countries (Vincente and Lopez, 2011). This puts the requirement of mitigation actions in a much clearer perspective and highlights the additional efforts necessary to provide viable proposals in order to narrow the digital gaps even further. A very recent study (Polykalas, 2014) looks into the historic evolution of the digital divide across a set of countries in the EU in order to examine the effectiveness of latest mitigation techniques and policies embedded in relation to this subject. Through the use of a set of factor indicators to assist with the analysis of statistical data, it has been concluded that the digital gap between the respective countries has been stable with very low rate of reduction. This may be the result of new technologies which are continuously being introduced, which alas, result in the widening of digital gaps within other aspects such as lack of technology adoption.

Research methodology

Recent studies have looked into the modern digital divide. Park and Lee (2015) conducted a research on smartphone users and compared data gathered with a set of lifestyles, online activity and information gaps. The authors have concluded that smartphone users seem to be more active in social and political issues when compared to non-smartphone users. Moreover, the use of mobile devices is leading to a faster adoption of digital technologies and is therefore presenting new dimensions of the digital divide (Prieger, 2013). The introduction of this new divide had been previously introduced by Schilit (1995) during his research which highlights that a modernized divide will be present due to mobile devices as well as mobile users. Gaved et al (2010) study the adoption of mobile learning through a cohort of younger students and note limitations such as the tested web applications' scalability and its network infrastructure. These studies are used to compile the conclusion that the divide based on ownership of smartphones has been decreasing, however the demand to utilize the user's experience is increasing.

Emergent technologies are continuously shifting and web applications are no longer seen as a content repository but rather intelligent and resourceful systems which are proficient and adaptable for users. In the education sector, current learning platforms are complex and lead to confusion on both the student's and teacher's part. The impact of such new technologies on education has been studied and broken down into four parts - the expanding knowledge domain, the requirement of an interlinked system, introduction of new forms of learning, and the requirement of consistent and appropriate content (Conole, 2010). Overcoming the digital gaps that e-learning students are exposed to is a challenge task, and many argue that a first step towards mitigating this aspect is by ensuring that academic teams are making full use of educational resources that are made available to them (McAndrew et al, 2009). This builds on Blin and Muniro's (2008) argument that virtual learning environments (VLEs) which help to mitigate the impact of emergent technologies in education, will be much more effective once resistance to the adoption of such technologies is reduced.

Adaptation of systems

As mobile learning is vastly increasing in popularity and usability, optimising techniques are being proposed to address device limitations and enhance distance-learning students' experience. The adaptation of personalised learning environments (PLEs) has been recently introduced, aiming at overriding the use of a standard VLE platforms and provide more personalized content and views to students. Methodologies include customisation and specialization of information systems for maximizing the efficiency of a learning environment when moving from a traditional classroom towards e-learning (Abazi et al, 2008). It has been argued that educational platforms are commonly implemented and developed for educational institutions and not for the end user who may have limited reliable resources and high speed connections (Johnson et al, 2007). A study of the digital divide within the Dutch population has been conducted by van Dijk and van Deursan (2014) during which the authors analyse the different patterns of information, operational and Internet skills when looking at a number of demographics such as education levels and age groups. It has been concluded that the effects of the noted gaps within limitations being experienced are more profound than having an unsuitable technological infrastructure.

Software adaptability has been an emerging need for business environments and has shifted the business focus from efficiency towards opportunity. Having an adaptable learning system will result in more coverage of different user requirements, targets and available resources. During the preliminary work in this domain, Fayad and Cline (1996) discuss four factors which are generally required when working on developing an adaptable system. These are extensibility, flexibility, tunability and fixability. The extensibility aspect tackles the need of scalability of the system, such as the ability for academics to add new interactive functions onto the VLE. The system needs to be flexible in order to allow for new and different material to be uploaded and made available to students. The performance tunability looks into the possibility of changing the system's infrastructure as appropriate, such as the reduction of network burden. Lastly, the system would definitely need to be quickly fixable in an efficient manner in order to reduce the recurring or replication of issues.

Interestingly enough, the same authors argue that quality is reduced when systems are adapted towards a vast range of different user requirements. This has however been followed up by other scholars (Wang et al, 2010 and Krongstie et al, 2006) as the flexibility, adaptability and tailorability of a learning environment may actually be interpreted as the system's quality level itself.

System optimising techniques

There are a number of aspects one can analyse within information systems adaptation to mitigate the digital divide. Interactive yet individual design would be one of the first steps towards a more adaptive system. A proposed approach has been put forward by He et al. (2008) which looks into a user interface object layout hierarchy. Through the use of Web Service Definition Language (WSDL), interface elements are assigned with horizontal or vertical associations, and are aligned depending on the end user's device display configuration. This however presents some limitations as the adaptation of learning environments requires more customisation and scalability. In their publication, Banati et al (2012) take this into consideration and discuss an enhanced approach which makes use of WSDL-TC (Temporal Customisation) in order to support multiple collaborative customisations. From a development perspective, this proposal looks into a dedicated set of resources and infrastructure for each entity (set of users). Deployments and updates needed to customise the system would only occur on the entity in particular and therefore reduces time, cost and the amount of resources required for utilization. These proposals however lack the consideration and work done on improving the user interaction therefore there is no end-user experience improvement produced from such approach.

Aiming at mitigating the digital divide for distance learning students, a 'learning computer' system has been proposed which consists of a device having all functions integrated for a specialized and individualized networked machine (Johnson et al, 2007). The authors agree with previous publications (Dietinger & Maurer, 1998 and Johnson et al, 2002) which concluded that placing more functionality on the student's computer is one of the key techniques towards reducing connectivity and broadband issues in such topics. The main features of this proposed tool is that the machine is controlled by the student and an integrated framework is based on an asynchronous and decentralized structure. There is no need of real time communication and system updates are done periodically by linking onto a central repository of resources. This use of asynchronous online discussions has also been highlighted by Mihail et al (2014), and Alencar & Netto (2011) who presented a prototype system which embeds a system-integrated Tutor Agent to assist with providing tutor feedback on such online forums. The aim of this system is to reduce the time-frame between questions posted by students and the Tutors' replies, as well as provide notifications of upcoming coursework submissions and monitor any incomplete tasks.

During testing stages of Johnson et al.'s (2007) proposed learning computer system, consistency and simplicity of the workflow was noted. The prototype however did not incorporate the highly-used mobile devices within its design and development. A similar approach was taken by Murray et al (2000) during their research conducted towards the need of intelligent adaptive hypermedia systems. Their conclusions determined that having a simple, user friendly interface design and powerful user features are essential towards improved information systems.

Related research has been conducted recently which aims at adapting information systems to end users with certain disabilities (Douce et al., 2010). As part of the EU4ALL framework, such mitigation involves the designing of an integrated system which includes a Content Personalization module to handle the requests put forward in order to access a particular learning resource and displays the most appropriate version to the user. Through localized modification of the VLEs digital content, adapted views are provided depending on the learning activity and device used.

The use of VLEs in delivering and teaching Science, Technology, Engineering and Mathematical (STEM) subjects in particular has also been looked into (Manesh and Schaefer, 2010). Since such topics require a set of laboratory work and training, virtual reality has been proposed to be combined with VLEs through careful design and implementation of three-dimensional representation capabilities. This approach promotes and encourages distance learning students to enrol and study such practical modules through the use of an interactive and personalized VLEs. A number of advantages were outlined by the authors as a result of adopting such platforms, these mainly being the cost reduction for the student and institution as well as having the option to work independently with no supplementary effort by the instructors. To illustrate the discussed approach, a software called Virtual Computer Integrated Manufacturing Laboratory has been presented to highlight the overall methodology of the operation taken which students are able to do so through virtual simulation models working in real time. The authors conclude that personalized virtual learning platforms are a step forward towards providing self-directed activity, motivation and augmented learning processes.

Another very interesting and applicable methodology proposed to adapt virtual learning environments has been presented and tested via a very popular platform called Moodle (Piovesan et al. 2012). The system is based on Schilit's (1995) research on context-aware mobile computing which denotes that there are four types of context: computational, user, physical and time. Piovesan et al.'s framework aims at providing a better learning experience through mobile devices, and is proposed to be done through a system which appoints an Agent in order to learn about the user's environment and display a more personalized view. Each student's connection speed will determine

the content and functional tools which they will access through the customised learning environment. The Agent's role in the infrastructure is to monitor this access, choose the appropriate material and tools, and then making these available to the end user in a more adaptable manner. The student's information is then logged on an XML file to record the network speed, IP address and the date of access. A number of applications and tools have been used in developing this prototype, including JavaScript and Mozilla's Firebug plugin to measure the user's connection speed. The proposed system is a very realistic approach towards adapting VLEs for students based on this particular demographic, however one can note that this framework looks into the connection speed only. As highlighted during previous literature, the unequal access to a learning platform may also result from other technical reasons such as the type of device being used.

Cloud computing mitigation techniques

Cloud computing is definitely not a new terminology to the information technology sector. The instant delivery of on-demand resources as a single utility and the cost reduction of building and maintaining an IT infrastructure are an asset to have embedded within a firm. Cloud-based applications allow for systems such as virtual learning environments to be hosted and made available through instant accessibility and improved flexibility. By working through and providing an intensive analysis on cloud computing services, Jalgaonkar and Kanojia (2013) investigate the advantages gained when customising learning environments by using cloud computing. An adoption strategy has been proposed with the aim of reducing concerns when implementing such cloud services within distance learning environments. The authors conclude that more flexibility and eventual cost reduction would be produced, also having the ability to access content at all times. This approach however does not consider the burden that is added onto the institution's network, which would result in an overall performance of the platform. Moreover, when working with cloud computing towards adapting a learning environment, one essential requirement that this entails is the desirability for teaching teams to be trained on the effective use of cloud applications (La Roux and Evants, 2011) and new systems (Fernández et al, 2014).

A similar concern is highlighted by Saunders et al. (2012) as part of their research conducted to study different applications' and files' bandwidth requirements. They noted that user adoption is highly limited due to the restriction of using different methods and practices. Another limitation is network infrastructure scalability as Internet Service Providers will not be supporting a huge increase in bandwidth capacity. Through the construction of an e-learning ecosystem based on a cloud infrastructure, Dong et al (2009) put forward a possible solution to the scalability issue through the use of an embedded monitoring ad hoc module. This part of the infrastructure is proposed to keep track of requests in order to effectively manage and utilize resources. A set of mechanisms are discussed by the authors, which in particular focus on the idea of early warning and self-recovering mechanisms. The first outcome is enabled once the demand on the cloud infrastructure reaches to a resource crisis and allows the system to optimise the allocations accordingly. The self-recovering section of the infrastructure tackles any hardware or software failures and substitutes resources as required. This e-learning ecosystem does not however deem to be appropriate in adapting onto virtual learning environments due to the intensive repository of resources required to be available at an instance, which in turn adds more towards the burden being applied onto the network infrastructure.

Optimising and balancing the load on the Cloud

During recent years, a number of soft computing techniques aiming at optimising and balancing load in cloud computing environments have been studied. Goyal (2014) discusses this through the comparison of a number of load balancing algorithms. The research concludes that Particle Swarm Optimisation is the algorithm that mostly improves quality and runs faster when it

comes to optimising the load balancing issue noted within cloud computing. This algorithm does this by iteratively attempting to improve the solution through two parameters: finding the best possible position and velocity of the particle which constitutes as a solution. This approach was originally proposed for mitigating social behaviour issues, however was later simplified and performed as an optimisation technique. A number of case studies on this topic have been looked into, including ElluminateLive (n.d.) platform that has been designed to configure data streams according to the end user's connection.

A framework proposed by Dong et al. (2009) is BlueSky and this aims to optimise and manage scalability and resources within e-Learning systems through the cloud. The design of this framework includes smart load balancing, efficient usage of resources in response to varying demand, and the sustainability of the e-learning system. This however does not eliminate the consistent concerns that arise through a number of critical studies done on the subject. Fernández et al (2014) present a detailed technical overview of cloud computing and look through its positive and negative aspects. Common disadvantages noted are the lack of scalability, possible security issues and the network traffic generated for connections with low bandwidth. The main argument put forward by these scholars is that cloud computing is not yet proficient enough to cope with all highlighted issues, but may tackle specific ones (Blanton & Schiller, 2010).

Customisation of web applications

As ubiquitous learning is gaining popularity nowadays, educational institutions need to cater for distance learning students as well as those on campus when accessing their learning platform during their educational studies. One approach towards this work is by looking into direct customisation of applications which hold learning material, communities for discussions and more.

An interesting proposed architecture has been put forward recently which investigates the possibility of amending and customising the user's view through the client side of the application (Troncoso and Cohen, 2011). The authors emphasize the need of a custom view which does not jeopardize an important advantage of using web applications - the ubiquity of having the site accessible from any computer. They present an architectural framework for such client side customisations which considers three parts: the application needing customisation, the browser used to run it and an external service used to store the customisation information. Whilst a detailed overview of the workflow between all parts has been proposed, this publication however lacks information on the algorithms used to customise the web application. The authors also note that the user will need to be prompted for identification each time a new web session is created. In the mitigation of digital divide where students are looking towards getting their academic resources as swiftly as possible, such information should ideally be only prompted for once.

Another similar proposal entailing the customisation of web applications from the client side, allows the end users themselves to select particular elements of the content and migrate the view to a different device (Ghiani, Paterno & Santoro, 2013). The aim of this system is to support dynamic composition and migration of sites from desktop to mobile devices. The architecture built for this is revolved around a migration platform called the Migration Client, which allows the user to specify the URL of the page to be managed and migrated. The workflow of tasks outlined by this proposed customisation may be summarized as firstly the user opens the website through the Migration Client, then enables the partial migration and selects the elements of interest. Once the request to migrate is sent by the user, the script is invoked and forwarded to the migration platform. Whilst the new target page is loading, the Migration Client prompts the user to authorize the incoming migration request. This framework has been highly tested through different users. The main conclusions drawn from these cases are that the majority of users opted to migrate the full site back to their desktop machine, since this device has enough interaction capabilities to support all

functionalities. It also emerged that interaction with a partial migration towards a mobile device consisted of less time when compared with using the original full page on a desktop machine. Nonetheless, all test cases reported that migration time would require to be reduced for efficiency and usability purposes. When looking at the usefulness of such proposed system, only one user seemed to not be encouraged to migrate just the useful part of the web application being tested. It has however been noted that the selection technique lacks intuition and has been described as a complex workflow.

A different context-aware customisation approach has been taken by Schreurs et al., (2008) where the authors present a system which dynamically generates and customises learning objects onto the platform. A detailed explanation of how such implementation works has been provided, however the conclusions of this theory do not take into consideration the actual creation of dynamic objects. The idea is that all course material is automatically structured and composed in order to achieve a highly structured and user friendly environment, however the e-learning module is not customisable by either the student or the learner.

Mistree, Schaefer and Panchal (2012) argue on the need of a mass customised learning programme and adopting this paradigm from product development to the education domain. One of the strategies being looked into for such a proposal is the need of a learning platform which promotes a learning-to-learn approach. The solution to this has been put forward as customising the platform on a few principles which include shifting the role of instructors and students to provide more opportunities and flexibility, setting learning communities, and focusing on higher level learning. Academic staff would be able to make better use of the tools and functionality available through such platforms to improve e-learning effectiveness (Wang, 2010). Such principles allow the learning platform to be designed in accordance to the appropriate customised programme. The information system which is used to provide a learning environment to distance learning students should be designed in an intertwined format for an appropriate interface, interaction, structure and content (Wang et al, 2010). System designers must definitely take into account the end user's support level, cross-platform compatibility as well as appropriate technical skills (Tingoy & Gulluoglu, 2012). The aim of such scholars are to highlight the need of applying customisation in educational environments and tools available, and hence presenting an appropriate self-directed learning platform for a more positive impact on distance education.

Findings

Following the critical study of past literature within the customisation and adaptation of virtual learning environments, all insight gained has been amalgamated and considered towards presenting a viable solution. The mitigation of digital divide requires a thorough understanding of the distance learning students' environment when accessing a learning platform during their academic studies. The proposed solution aims towards a method which caters for each pupil individually, through the measurement of a number of demographics which make up the user's impediment. The methodology initiates by implementing a device test to study and get the appropriate information in order to understand the current working environment. Such test will then result in an adaptation and customisation of the online platform displayed, depending on the information located.

The workflow of this device test initiates as soon as the student logs in onto the particular VLE. Upon successful login, a prompt is displayed for the pupil to provide authorization of the test being performed on their device and location. Following the positive confirmation of the checks to be done, the test is initiated for the appropriate measures and information to be gathered and logged, for a customised view of the VLE being accessed. Understanding and analysing the user's working environment includes getting the geographical location of the access point. This is collected either

by determining the latitude and longitudinal coordinates of the GPS location, or through the network IP address.

Connection properties

The user device test starts off by measuring the bandwidth connection speeds and this is firstly done by pinging the connection and logging the download and upload speeds. Any delays measured when requesting, processing and transferring data between the client and the server sides are also stored to analyse any latency experienced. This is mainly measured through the "tracert" command which provides three millisecond time-frames of the latency covered to load each hop when accessing a site.

The connection ping as well as the trace command are both assigned with a particular appropriate threshold towards which the overall connection will be labelled as being low or high speed. The knowledge gathered following these checks will assist when determining the arbitrary megabits per second connection measure which will dictate whether VLE features are to be customised or not. In case a low connection speed is returned, the platform should then omit large demanding features including videos and auto-play elements. Moreover, images are displayed through an appropriate option of either presenting thumbnail sized pictures, or in a lower resolution. When working through such a high connection burden, additional social media and promotional links and updates should definitely be discarded from the platform.

Device properties

Through the literature research done, it has been highly noted that the use of mobile devices is exponentially increasing in usage and demand within developing countries. This therefore indicates that learning platforms are required to cater for the appropriate personalization of the site's user interface when using such devices. In fact, the basic check within this domain is to log the device type and its screen size. A very powerful tool which works on the client side to assist with the adoption of systems is a JavaScript repository, the Wireless Universal Resource File (WURFL). The WURFL.js file incorporates a number of functions which identify information about the end user's device. Statements such as "WURFL.form_factor", "WURFL.resolution_height", and "WURFL.resolution_width" return the specific screen dimensions as well as determine whether the user is working on a mobile or a desktop device. "WURFL.is_full_desktop" also denotes whether the device supports a full desktop view of the platform page. This would then base on Ghiani et al.'s (2013) work where the load request reverts back to the full site if enough capabilities are present. On the other hand, depending on the physical device that the student is accessing the VLE through, the webpage is adaptable through the use of Web Service Definition Language Temporal Customisation to amend the object layout on screen. This is an approach which was introduced by Banati et al. (2012) in order to shift the page elements onto a vertical or horizontal hierarchy as appropriate by working on minimal resources and infrastructure required on the server side. Such technique is linked with the data gathered through WURFL when studying the student's device in order to provide a more intelligent and efficient interaction with the VLE.

The JavaScript WURFL file also incorporates the use of CSS to enhance a user's display, depending on the study of their working environment. When looking into the device physical dimensions which may be limited, features such as the page's header and footer should definitely be hided in order to allow critical VLE links and text to be displayed in a reliable and user friendly manner. Another optimisation technique is adapting the page tabs and menu bars within the platform onto a collapsible functionality. This allows the system to be customised specifically and particularly for the student's device which is being used to access and work onto the VLE.

System properties

Additional device checks may be performed through the authorized test upon the student's login. Such information includes an understanding of the operating system and the browser being used since these are key elements of web pages not displaying consistently on every device. This data is collected through JavaScript's WURFL repository which returns the operating system name and browser details of the requesting device. Once gathered, this information is very useful towards additional optimising techniques to incorporate for a student's display. Looking into the end user's operating system, this effects how text on the learning platform is to be presented. In cases where a different OS is being used may result in particular fonts to not be compatible which result in an undesirable change in text length and height. A Mac computer for example has different text smoothness when compared to Windows (Browne, 2014). This is mitigated by understanding the user's operating system in order to determine whether this corresponds with the server's OS. In case there is a difference, standard fonts are automatically displayed to prevent the user from having to purchase new web fonts or experience a cluttered page. Moreover, since different browsers render and interpret webpage instructions differently, logging the browser being used by the student is vital. WURFL.js provides this information in order to target and load the appropriate HTML, JavaScript and CSS and provide a customised view.

Bandwidth and load optimising techniques

When looking into additional server side adaptations which assist with improving and enhancing a distance learning student's access to VLEs, implementing an integrated infrastructure which is based on asynchronous and decentralized structure is a recommended way forward as Johnson et al. (2007) proposed. This is because the demand on broadband connection and load is highly reduced when omitting real time communication within the majority of pages in the system. Moreover, using bandwidth-managed deployments and updates incorporated within the platform is also proposed in order to reduce congestion during peak network usage.

Results and Findings

The proposed system gathers a number of different technological knowledge specifically and personally for a distance learning student in order to amalgamate the results and customise the VLE access. When considering the logs of information collected which mainly includes physical device dimensions, connection aspects, system properties as well as the geographical location, these assist with the adaptation of different sections of the platform according to the end user's working environment. The optimised view is displayed and linked with the defined criteria and preset threshold in order to customise the webpage's features and elements accordingly.

The below flowcharts in Figure 1 and 2 provide a generic overview of the workflow being undertaken when the proposed system adaptation techniques are in place in order to mitigate the digital divide within distance learning students.

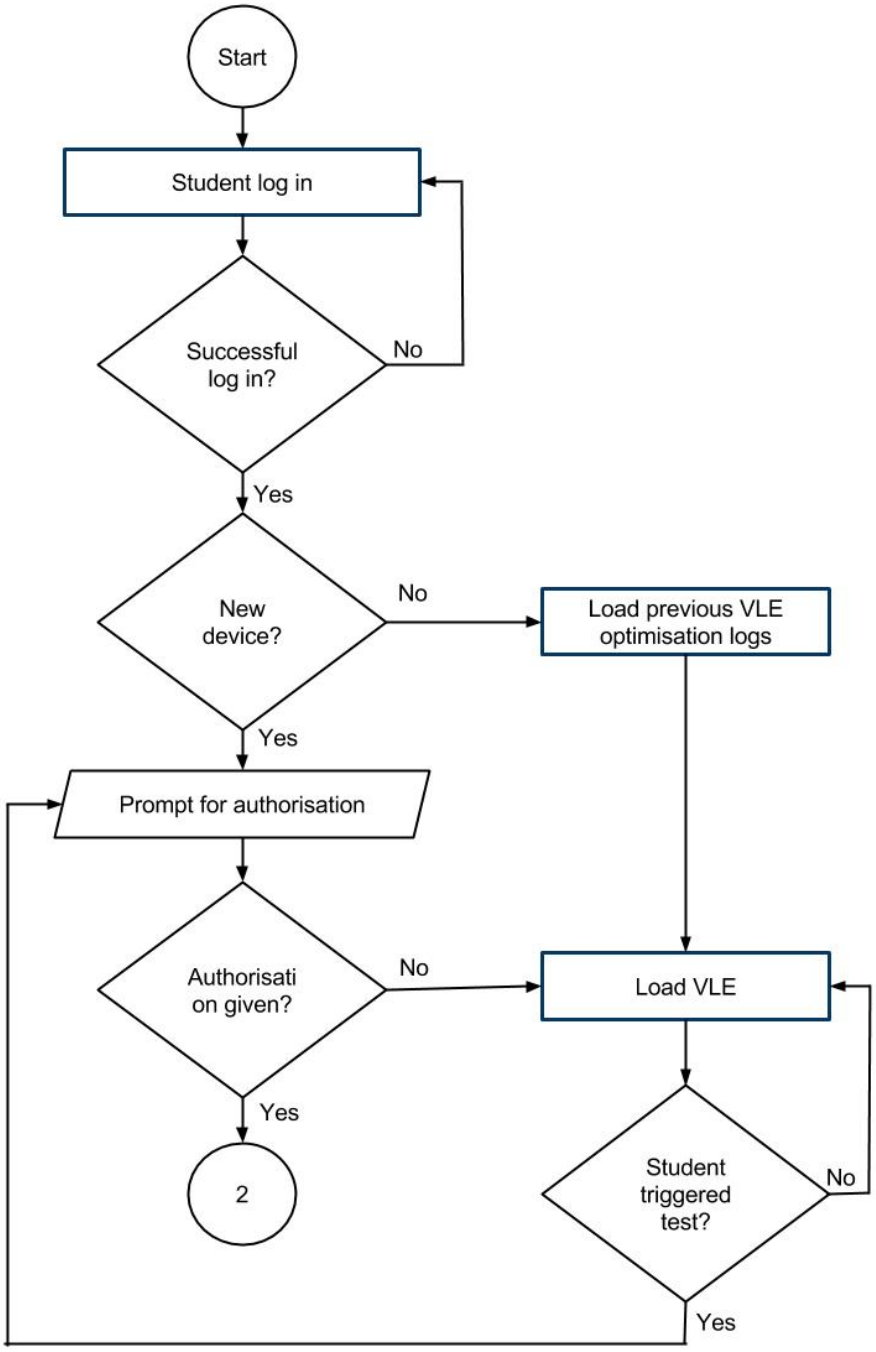

Figure 1. Process flow diagram for proposed adaptive VLE system – Part 1

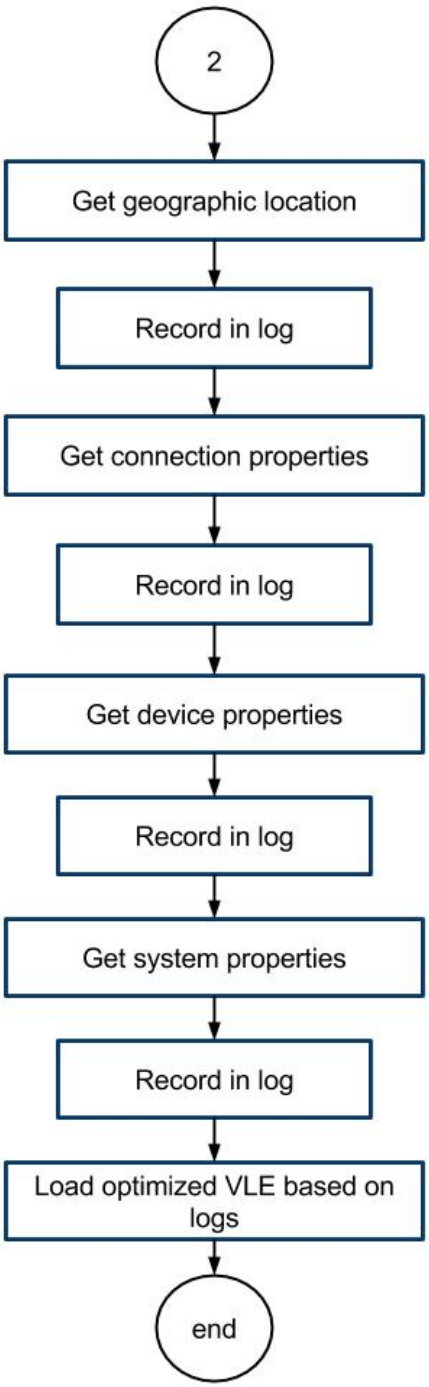

Figure 2. Process flow diagram for proposed adaptive VLE system – Part 2

To inhibit from displaying consistent disturbing notifications to pupils, the discussed device and working environment checks for the relevant system adaptation is set to be prompted periodically. This is done since mobile devices are usually constantly used by the same user, therefore the logged records which are gathered throughout the above highlighted process are recorded and interlinked with the student's account on the VLE. Whenever the particular pupil logs in and the system does not detect a change in the device being used, the pre-set VLE optimisation techniques are automatically assigned. Furthermore, this allows for an instant detection of when a new type of device is used to log onto the particular profile at which point the tests are triggered. To provide as much flexibility and efficiency as possible, the user is nonetheless able to activate the checks at any point as desired and necessary.

Throughout the development of the proposed system, a set of assumptions and requirements have been set as a basis for the research. Firstly, the distance learning student is assumed to have a mobile or desktop device available to access VLEs as well as a connection established when such assess is required. In cases where mobile devices are used, smartphones are a requirement towards being able to access a webpage and work on a learning platform.

Based on the literature review conducted, it has been determined that the trigger towards initiating the device test has been linked with the end user first logging in onto the VLE and then detecting a change in the device being used. This therefore noted that the proposed system would be even more effective when the particular browser's cache and cookies are used. Following the first device test, cookies are then used to save the device and user information while cache allows for quick access when logged back in.

Conclusions

This paper provides a detailed and critical analysis of the current optimisation techniques proposed and implemented for VLEs. The aim of the research is towards mitigating the digital divide in this domain, which has been noted in different forms and stages over the past years. A scrutinised study has been done on scholars presenting different ways to reduce the impediment that distance learning students experience when particular resources and high speed connectivity are limited. The conducted research provides a set of different demographics and aspects that this divide is looked into, aiming at investigating and proposing new views of mitigation techniques.

The proposed solution to the noted problem within this digital divide has been presented and discussed in detail. A set of highly analysed current customisation methods as well as innovative approaches have been amalgamated towards producing an extensive and intelligent adaptive system. The combination of working on both client and server side techniques allow for students to receive an enhanced and personalised view of the platform. This provides an optimal way forward when aiming at reducing the current inequalities experienced in such digital divide. Through the study of a distance learning student's environment, broadband and technological aspects are vastly considered through the adoption of new technology which provides the right tools to gain such required insight. The knowledge being collected within all property types for a student are ultimately combined in an original manner for an enhanced and adaptable virtual learning environment.

Suggestions

Additional work may be done on this proposed system which aims at mitigating the digital divide experienced when accessing educational learning platforms through distance learning. The discussed amalgamation of the techniques and presentation of new concepts to incorporate do require more work in order to set up a prototype of such interlinked system that studies and

understands the student's learning environment. Through the development of such adaptation methodologies, tests and use cases may be designed for further analysis on additional aspects to consider when producing such a complex and broad adaptable system.

Moreover, future work may incorporate the study of distance learning digital divide through a different perspective and other types of end user. These may include the analysis of pupils who experience different learning difficulties and are consistently interacting with an educational institution's VLE. The same concept may be adapted towards mitigating the divide experienced within developed countries who are looking at having more intelligent systems available. Through the understanding of issues currently experienced in different dimensions of the digital divide, a mass customisable and personalised access to such systems is definitely an optimal way forward.

Literature

Abazi, A. Bekim F. and Henry D. 2008. *The application of technology in enhancing multicultural and multilingual aspects of education: Digital divide into digital opportunities.* Information Technology Interfaces. 30th International Conference on. IEEE.

Alencar, M. and José M N. 2011. *Improving cooperation in Virtual Learning Environments using multi-agent systems and AIML.* Frontiers in Education Conference (FIE). IEEE.

Banati, H. Punam B. and Piyush M. 2012. *WSDL-TC: Collaborative customization of web services*. Intelligent Systems Design and Applications (ISDA). 12th International Conference on. IEEE.

Bélanger, F. and Lemuria C. 2010. *The digital divide and internet voting acceptance.* Digital Society. ICDS'10. Fourth International Conference on. IEEE.

Blanton, S. and Schiller C. 2010. *Is there safety in the cloud.* EDUCAUSE Quarterly 33.2, p. 381-400.

Blin, F. and Morag M.2008. *Why hasn't technology disrupted academics' teaching practices? Understanding resistance to change through the lens of activity theory.* Computers & Education 50.2 p. 475-490.

Browne, E. *Why your website looks different on different screens*. [Online] Available from: http://rye.agency/blog/why-your-website-looks-different-on-different-screens, [accessed 3/09/2015].

Chinn, M D. and Robert W F. 2006. *The determinants of the global digital divide: a cross-country analysis of computer and internet penetration.* Oxford Economic Papers.

Conole, G. 2010. *Bridging the gap between policy and practice: a framework for technological intervention.* Journal of e-Learning and Knowledge Society-English Version 6.1.

Corrocher, N. and Andrea O. *Measuring the digital divide: a framework for the analysis of cross-country differences.* Journal of Information technology 17.1 p. 9-19.

Deursen, A JAM, Helsper, E. and Eynon, R. 2014. *Measuring digital skills: from digital skills to tangible outcomes project report*.

Dietinger, T. and Hermann M. 1998. GENTLE (GEneral Networked Training and Learning Environment). na.

Douce, C. Porch, W. and Cooper, M. 2010. *Adapting e-learning and learning services for people with disabilities*.

Dong, B, et al. 2009. *An e-learning ecosystem based on cloud computing infrastructure.* Advanced Learning Technologies. ICALT 2009. Ninth IEEE International Conference on. IEEE.

Dong, B, et al. 2009. *BlueSky cloud framework: an e-learning framework embracing cloud computing*. Cloud Computing. Springer Berlin Heidelberg, p. 577-582.

Elluminate, n.d. *'Elluminate live! Bandwidth management'*. [Online] Available from: http://ltech.alliant.edu/uploads/2/2/4/5/2245311/elluminate_live_-_bandwidth_management.pdf, [accessed: 12/07/2015].

Falch, M. 2007. *Penetration of broadband services–The role of policies*. Telematics and Informatics 24.4 p. 246-258.

Fayad, M, and Cline M P. 1996. *Aspects of software adaptability.* Communications of the ACM 39.10 p. 58-59.

Fernández, A, et al. *E-learning and educational data mining in cloud computing: an overview.* International Journal of Learning Technology 9.1 p. 25-52.

Gaved, M, et al. 2010. *Using netbooks to support mobile learners' investigations across activities and places.* Open Learning 25.3 p.187-200.

Ghiani, G. Paternò, F. and Santoro, C. 2013. *Interactive customization of ubiquitous Web applications.* Journal of Visual Languages & Computing 24.1 p. 37-52.

Goyal, A. 2014. *A Study of Load Balancing in Cloud Computing using Soft Computing Techniques.* International Journal of Computer Applications 92.9.

He, J, et al. 2008. *An adaptive user interface generation framework for web services.* Congress on Services Part II. SERVICES-2. IEEE.

Jalgaonkar, M. and Kanojia, A. 2013. *Adoption of Cloud Computing in Distance Learning.* International Journal of Advanced Trends in Computer Science and Engineering 2.1 p. 17-20.

Johnson, R, et al. 2007. *The learning computer: low bandwidth tool that bridges digital divide.* Journal of Educational Technology & Society 10.4 p. 143-155.
Jones, G. and Sallis, E. 2013. *Knowledge management in education: Enhancing learning & education*. Routledge.
Krogstie, J. Sindre, G. and Jørgensen, H. 2006. *Process models representing knowledge for action: a revised quality framework*. European Journal of Information Systems 15.1 p. 91-102.
Kukulska-Hulme, A. 2012. *How should the higher education workforce adapt to advancements in technology for teaching and learning?*. The Internet and Higher Education 15.4 p. 247-254.
Kvasny, L, et al. 2008. *Gendered perspectives on the digital divide, IT education, and workforce participation in Kenya.* Education, IEEE Transactions on 51.2 p. 256-261.
Kyriakidou, V. Michalakelis, C. and Sphicopoulos, T. 2011. *Digital divide gap convergence in Europe*. Technology in Society 33.3 p. 265-270.
Manesh, H., and Schaefer, D. 2010. *Virtual Learning Environments for Manufacturing Education and Training.* ASEE Computers In Education Journal (CIE).
McAndrew, P, et al. 2009. *OpenLearn research report 2006-2008.*
Mihail, R P. Rubin, B. and Goldsmith, J. 2014. *Online discussions: improving education in CS?*. Proceedings of the 45th ACM technical symposium on Computer science education. ACM.
Mistree, F, Schaefer, D. and Panchal J H. 2012. *Mass-customization: From personalized products to personalized engineering education.* INTECH Open Access Publisher.
Montagnier, P. and Wirthmann, A. 2011. *Digital Divide: From computer access to online activities–A micro data analysis.*
Murray, T, et al. 2000. *Evaluating the need for intelligence in an adaptive hypermedia system*. Intelligent Tutoring Systems. Springer Berlin Heidelberg.
Park, E A. and Lee, S. 2015. *Multidimensionality: redefining the digital divide in the smartphone era.* 17.2 p. 80-96
Pearce, K E. and Rice R E. 2013. *Digital divides from access to activities: comparing mobile and personal computer internet users.* Journal of Communication 63.4 p. 721-744.
Piovesan, S D, et al. 2012. *Adaptive virtual learning environment*. Global Engineering Education Conference (EDUCON), IEEE.
Polykalas, S E. 2014. *Assessing the evolution of the Digital Divide across European Union.* Web and Open Access to Learning (ICWOAL). International Conference on. IEEE.
Prieger, J E. 2013. *The broadband digital divide and the economic benefits of mobile broadband for rural areas.* Telecommunications Policy 37.6 p. 483-502.
Sanders, L S. 2011. *Improving Distance Education Program Quality Through the Implementation of a Center for Excellence.* Distance Learning 8.1 p. 37.
Saunders, J D. McClure, C R. and Mandel, L H. 2012. *Broadband applications: Categories, requirements, and future frameworks.* First Monday17.11.
Schreurs, J. Vanhove, B. and Al-Zoubi, A Y. 2008. *Assembling content into dynamic learning objects versus authoring of e-learning courses.*
Schilit, W N. 1995. *A system architecture for context-aware mobile computing*. Diss. Columbia University.
Taylor, R D. and Schejter, A M. 2013. *Beyond Broadband Access: Developing Data-based Information Policy Strategies*. Fordham Univ Press.
Tingoy, O. and Gulluoglu, S S. 2012. *Effects of culture on distance learning in higher education in the light of digital divide and multicultural: Curriculum and design strategies*. Problems of Cybernetics and Informatics (PCI), IV International Conference. IEEE.
Troncoso, R M. and Cohen, J N. 2011. *Ubiquitous client side customization of Web applications.* Web Systems Evolution (WSE), 13th IEEE International Symposium on. IEEE.
van Deursen, A JAM, and van Dijk , J AGM. 2014. *Internet skill levels increase, but gaps widen: a longitudinal cross-sectional analysis (2010–2013) among the Dutch population.* Information, Communication & Society 18.7 p. 782-797.
van Deursen, A JAM, and Van Dijk, J AGM. 2014. *The digital divide shifts to differences in usage.* New Media & Society 16.3 p. 507-526.
van Dijk, J AGM. 2006. *Digital divide research, achievements and shortcomings.* Poetics 34.4 p. 221-235.
van Dijk, J, and Hacker, K. 2003. *The digital divide as a complex and dynamic phenomenon.* The information society 19.4 p. 315-326.
Vicente, M R. and López, A J. 2011. *Assessing the regional digital divide across the European Union-27.* Telecommunications Policy 35.3 p. 220-237.
Wang, J. Solan, D. and Ghods, A. 2010. *Distance learning success–a perspective from socio-technical systems theory.* Behaviour & Information Technology 29.3 p. 321-329.
Wang, T H. 2010. *Web-based dynamic assessment: Taking assessment as teaching and learning strategy for improving students'e-Learning effectiveness.* Computers & Education 54.4 p. 1157-1166.