Augmenting E-learning tools for STE disciplines and resource constrained environments

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Abstract. E-learning includes elements of both on-line and off-line learning (and/or distance learning). Various Learning and Course Management Systems (LCMS) are used for blended or hybrid learning in Science, Technology and Engineering (STE) disciplines, where they provide a defined (guided) path of study intended for collaborative groups of learners (such as a typical classroom) within the confines of a closed web-based (online) environment. In the blended learning approach, e-learning platforms augment or enhance the face-to-face (traditional) approach to teaching, focusing on the adaptation and delivery of pedagogical material. Key challenges affecting the wider use of e-learning platforms in STE disciplines include lack of adequate support for practical/laboratory work, the need to reformat/transform existing pedagogical content for on-line use, the added demands of on-line interactivity on the part of instructors/providers of content and the accessing them from resource constraint environments. This paper presents two techniques that could be used to reduce the overhead of reformatting or adapting pedagogical material for use as learning objects, as well as, addressing the fundamental challenge of accessing/using online educational resources from resource constrained environments. The results obtained from experimental study are also presented and discussed as potential enhancements for self/personal and group learning.

Keywords: e-learning, resource constrained environments

1 Introduction

Historically, training of learners has always been facilitated around a face-to-face interaction between a provider of content (teacher or instructor) and a select group of learners. The invention of writing aided training of learners by allowing the easy recording of content for consistency. While, the invention of the printing press allowed the reproduction of instructional (objects) content [18] and allowed scalability to a broader group of learners. The instructional (learning) content/object may be taken as any granular entity such as instructional (lecture) notes, objectives/outcomes, and other aid or content that is used for learning, instruction, and teaching.

In many educational institutions, the training of learners has evolved to include the interactive delivery of grouped instructional content supported with additional information (mainly experiential in nature) aimed at building individual understanding, know-how and soft skills [16]. The subject specific grouping of instructional content about concepts (not practical applications) within the subject constitutes the theoretical aspect of its pedagogy. In Science, Technology and Engineering (STE) disciplines, the delivery of theoretical instructional content happens within a classroom environment, while an associated practical hands-on component occurs in a controlled laboratory environment [14]. Practical laboratory work is both an important and integral component in training engineers [19], and is vital for developing skills that stimulate creative problem solving capabilities and provide experiential insight into real world problems [7]. Products of STE based training programmes are responsible for designing, implementing and maintaining basic and important infrastructures that are capable of transforming a society [20] and new multidisciplinary sectors like telemedicine are examples of the innovative application of STE know-how [11]. In many nations, the application of STE know-how is now-a-days directly related to reducing inequality, improving quality of life and collective prosperity.

The use of e-learning tools in STE disciplines is challenging mainly because they are designed for use in many disciplines which do not all share a common approach to training. Various authors including [15] [3] and [9] all share the view that the lack of adequate support for practical laboratory or hands-on aspects of pedagogy is the largest barrier to widespread adoption/use of on-line courses in STE higher education. Experiential evidence at many STE institutions suggests that the need to reformat existing pedagogical material is also a strong barrier. Followed by the overhead on instructors as content providers to maintain an on-line presence for responding to requests and/or providing guidance to learners in the anytime, anywhere spirit of on-line interactions. This overhead is additional to regular classroom interactions in the blended form of e-learning.

Accessing e-learning platforms and other on-line educational resources from resource constrained environments is challenging especially when bandwidth is inadequate or a general lack of on-demand connectivity; In certain environments, academicians (content providers and learners) have to juggle between filtered/restricted access available at their institutions and multiple (concurrent) paid subscriptions (data plans) from different mobile providers in a bid to have access to the internet. Even then, it is not uncommon for data access on mobile networks to fail intermittently and without warnings. Learners in such environments find it difficult to participate in scheduled on-line class activities or even use on-line resources for self-paced learning and it is usual for learners to resort to massive download of learning contents late in the night or very early in the morning for subsequent or later use, if they can support the costs of access.

This paper begins by briefly examining ways of addressing the challenge of supporting practical laboratory or hands-on aspects of STE pedagogy in e-learning platforms. However, the main contributions are two techniques: the first addresses the burden of reformatting existing pedagogical material for on-line use and the second facilitates the use of e-learning platforms from resource constrained environments. Section 2 of this paper presents e-learning, discusses existing augmentations to e-learning platforms specific to STE disciplines, while section 3 presents two augmentations that address the challenges of reformatting existing pedagogical content for on-line use as well as the provision of on-line learning content to learners in resource constrained environments. Section 4 presents the application of the augmentations presented in Section 3 along with some feedback obtained from learners. Section 5 concludes the paper and discussed our future activities.

2 Background

In on-line E-learning systems, platforms or tools such as Learning Content Management systems (LCMS) focus on supporting the learning process: they include the storage and on-demand provision of pedagogical/training material to learners while also managing and coordinating some other aspects of the process. Virtual Learning Environment (VLE), focus on providing an environment for learning as opposed to managing the course and learning process. LCMS and VLE typically include a Content Management System (CMS) that is fundamental in the storage and management of content. Learners interact with LCMS/VLE mainly through the traditional computer input devices (keyboard and mouse), while the output is mainly through on-screen display of text, diagrams and multimedia objects.

A well known example of an LCMS is the free and open-source software known as Modular Object-Oriented Dynamic Learning Environment (MOODLE). It is relatively easy to deploy (and/or upgrade). And may be used to provide full, hybrid or blended e-learning, with well-defined roles of teacher, instructors, tutors and learners. Table 1 presents some relevant characteristics of the MOODLE LCMS platform.

In MOODLE, all interaction is over a web-based interface and the platform may also be used for some form of assessments including quizzes, multiple choice questions (MCQ) and short essays with optional automatic grading. Thanks the WWW and HperText Markup Language (HTML) heritage, LCMS and e-learning platforms support the storage, manipulation and presentation of text, graphics and multimedia objects or contents.

Figure 1 shows the use of e-learning platforms such as MOODLE for training/learning in STE disciplines. As shown, these platforms are deployed to support the classroom aspects of pedagogy in the blended learning approach. Most e-learning platforms such as MOODLE are designed for use in many disciplines and so do not provide features to support special needs of a particular discipline including the practical laboratory or hands-on aspects of pedagogy that is vital in STE disciplines. Several well-known ways of addressing this challenge are discussed in the following paragraphs.

In the practical laboratory aspect of pedagogy (see Figure 1) in STE disciplines, the apparatus (equipment) is physically located at a fixed location (inside a physical laboratory), and learners have to co-located within the laboratory to

Table 1. Summary features/characteristics OF MOODLE e-learning platform

Features	Notes
Cost	Free and Open-Source Software
Deployment complexity	Simple to install (web-server with PHP and database)
Low-level customisation	Requires good or in-depth technical know-how and skills in PHP programming language
Supported models	Full, blended and hybrid e-learning
Human Computer interface	Computers and mobile devices with contextual menus that change based on role or activity
Multimedia learning objects/contents	Supported
Forms of assessments	Quizzes, MCQ, short essay answers
Additional interactivity	Web 2.0 tools (blogs, wiki, forums), Conferencing tools (chat) and social networking tools.

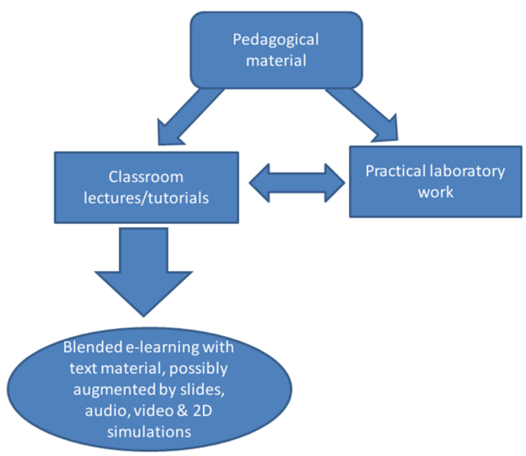

Fig. 1. Application of e-learning tools in STE discipline

use them [6]. Creating a laboratory for hands-on practical work in most STE disciplines is not cheap. Moreover, as physical locations, they are always limited in capacity and may also be costly and/or difficult to expand [1]. Sometimes, the apparatus (located within an STE laboratory) may be accessible on-line or over a communication network (for example the internet) as remote laboratories.

Remote laboratories are useful for augmenting e-learning platforms as they allow learners to carry out practical hands-on experiments on-line, that is, without being physically co-located with the equipment. Typically in a remote laboratory, the learners would access the laboratory through a web-browser which in-turn uses a back-end server to interface with the laboratory equipment and also coordinate access and use [8]. Within the confines of the computer based represented of an apparatus as provided in remote laboratory, a learner provides input/control information that is transmitted to the physically distant equipment where the experiment is performed and the resulting output/results from the equipment display to the learner. Remote laboratories have to be operated according to a fairly rigid schedule to accommodate both physical and remote use; they are not well suited for experiments that require manual interventions such as mixing chemicals or physically combining electrical circuits.

Generally, simulation allows learners to explore the item or situation being studied sometimes in an interactive manner that aids the ability to understand systems [17]. In the context of e-learning platforms, simulations can be used to improve learner understanding of abstract concepts as well as, provide practical hands-on training [4]. In most cases, the learner is able to vary input parameters in the simulated environment and with minimum delay, observe and analyse the resulting output [4]. There are already many on-line or web-based simulation tools created using Java and JavaScript that may be used to augment e-learning tools in STE disciplines. Also, other tools such as mathematica, MATLAB and LabView may be used to develop/create simulations.

Thanks to advances digital video compression, e-learning platforms can also include video based learning objects or provide seamless access to video obtained from various on-line service including Internet Archive (a digital library of free Books, Movies, Music & Wayback Machine) and YouTube (a video sharing website). Video lessons for e-learning are typically created for the purpose of on-line learning and are usually not longer than 20 minutes in duration to avoid learner distraction or boredom.

In this section, we have briefly reviewed three ways for augmenting e-learning tools, namely: the use of remote laboratories, the use of virtual simulations and the use of video lessons. While, the first two are aimed at addressing support for practical hands-on aspect of STE pedagogy, they usually require some additional reformatting of pedagogical content to match the practical. For example, pedagogical text may have to be reviewed and aligned with whatever experiment is available in the remote laboratory or on-line simulation tool. The last technique discussed also requires the reformatting/transformation of existing pedagogy material by content providers especially to cater for the shorter duration of lessons.

Clearly, on-line resources presented are external to the LCMS platforms, integration is usually in the form of loose couplings (external links) that may sometimes make the learning process challenging, disorganised for the learner and learning objects (contents) difficult to reuse [23].

3 Methodology - Augmenting e-learning

The authors of [15] in their comparison of on-line to face-to-face delivery of undergraduate level learning material in digital electronics warn of the importance of maintaining the standards and criteria of traditional hands-on experience (and pedagogy) from face-to-face delivery if learning effectiveness is to be achieved from on-line delivery. This warning is also applicable to any new designs of learning experiences, processes and environments and educational approaches. In this section we discuss two techniques for augmenting e-learning platforms, that are later employed in section 4. The first involves direct recording of classroom lessons, while the second focuses on creating an off-line copy of core learning objects contained in the LCMS for use by learners from resource constrained environments. The techniques respectively address the burden of reformatting existing pedagogical material for online use as well as the use of e-learning platforms from resource constrained environments.

3.1 Recording of classroom lessons

The typical classrooms have limited capacity and in many institutions, they are shared according to strict schedules. Historically, classrooms have always included a blackboard or wide surface suitable for writing by the instructor. The modern or multimedia enabled classrooms now include a projector, a display screen and possible a desktop or laptop computer device. During face-to-face taught lessons, learners often make textual (or audio) recordings for personal use that document to a limited extent the information exchange along with the emphasis and atmosphere of the classroom. Subsequently, these recordings are re-utilized by the physically present students as study aids.

Fig. 2 shows a classical classroom layout where audio-visual recording devices (microphones and cameras) have been added. As show in Fig. 3, three devices have been positioned to capture the frontal area of the classroom that is the instructor, the projection screen and blackboard as this produces a video image taken from the perspective of learners seated within the classroom during a taught lesson. Other layouts are possible depending on the available equipment, for example, a capture device may be located behind all learners to capture the display/instructor area using wide zoom lenses. The use of carefully positioned fixed location capture devices is recommended to avoid becoming a source of distraction; however, use of a single manned camera unit is also possible.

By using a classroom configured as shown in Fig. 2, content providers can capture their face-to-face classroom taught lessons as digital video for on-line use. Optionally, post processing or editing may be performed on the lessons to

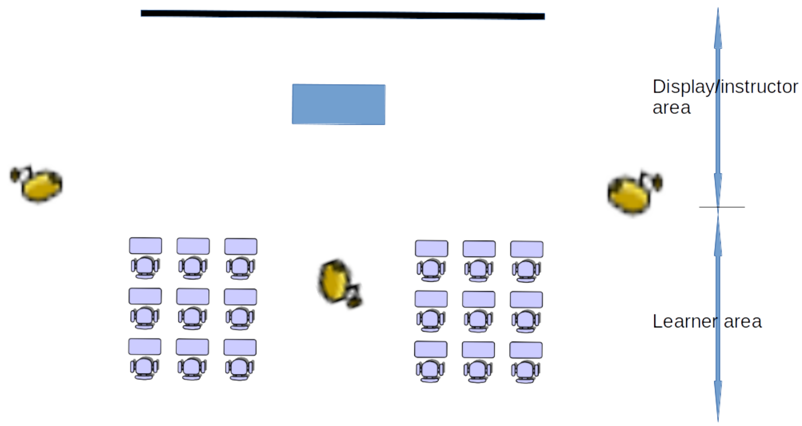

Fig. 2. Classroom equipped with audio-visual capture devices

cater for duration before upload to the LCMS platform. Subsequently, supplementary materials such as lecture notes, exercises, assignments, summaries and other relevant notes by tutors or students may be added to the captured video lessons. Over the course of a semester or period of teaching, the lessons and supplementary materials together create an equivalent on-line course that mirrors the existing standards and criteria of the face-to-face delivery of pedagogical content.

3.2 Portable off-line archives of learning resources

The second technique presented here addresses the use of on-line learning content from resource constrained environments. Internally most LCMS platforms create content dynamically as it is often necessary to personalize learning objects according to the progress and preferences of individual learners. For many text-based platforms, it is not uncommon for parts of raw text to be stored in some database engine and only extracted for creation of pages when required. While this suggests possible incompatibilities between e-learning platforms, many of them support the exportation of learning content to a standard format such as the Sharable Content Object Reference Mode (SCORM) or the IEEE Learning Object Metadata (LOM). Importing SCORM or LOM formatted data require each user to deploy an equivalent LCMS platform before they can access or re-use the content. The complete or successful importation of all data from standards based exportation process is not always guaranteed across different brands/versions of learning platforms. The SCRON/LOM based approach also requires the cooperation of the content provider or a suitable administrator to create a SCORM or LOM copy of an existing course.

Fig. 3 present an alternative process to the use of SCORM objects that allows an end-user or learner to create a portable off-line copy of on-line learning

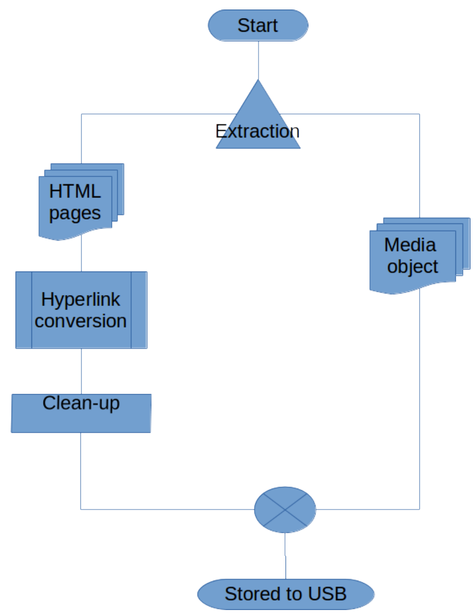

Fig. 3. Flowchart of off-lining process

contents [21]. As shown, the first step involves extracting the pedagogical content from the e-learning platform. For example, appropriate tools could be used to download or mirror the HTML pages independently from media or video files. The HTML pages would undergo a predefined process where absolute links are converted to relative ones. This is followed by a clean-up process that would replace the media-player with a suitable equivalent, as well as, remove search dialog-boxes and other elements that would otherwise fail. The results are then merged with the downloaded media files to create a portable archive on a suitable device such as a USB disk. The process (Fig. 3) described here require some additional refinement based on the LCMS platform and HTML customizations in use. The extraction process may involve providing suitable authentication credentials to scripts or helper tools.

Group based learning with the portable off-line archive is possible when high quality video files are used as these may be projected on large screen displays using video projector devices. Alternatively, the video lessons may be viewed by groups of learners together, such as in a classroom environment during a normal lecture and in combination with other active learning techniques such as group discussions [22]. The next section discusses the application of these two techniques presented here along with results obtained.

4 Results - Augmenting MOODLE

In this section, we present results from two separate experiments: first a year long experiment leading to the creation of an e-learning platform from recordings of classroom lessons as discussed in section 3.1 and a second experiment that involved creating a portable off-line archive for the LCMS created in the first experiment and subsequent distribution to institutions world-wide.

4.1 Experiment 1 - Recording of classroom lessons

Recording of classroom taught lessons as described in section 3.1 was applied during a yearlong taught diploma in Physics [13] for 15 graduate students from 10 different countries. A course-work only format was used that required only a final examination without the need for a dissertation.Students were required to take all courses and to successfully complete all examinations. Despite the language diversity among the group of learner, lessons were taught using the English language by a single lecturer per subject except for "Physics of the Earth System" which had four different lecturers/instructors. Three subjects also ran separate tutorial classes (with tutors), while for the other subjects, tutorials were an integral part of the classroom lessons.

Table 2. Number of hours of recorded video per subject/course

Subject	Hours
Mathematical methods	68
Classical Mechanics	32
Advanced Electromagnetism	30
Advanced Quantum Mechanics	60
Statistical Mechanics	58
Solid State Physics	40
Physics of the Earth System	36
Relativistic Quantum Mechanics	36

Table 2 shows the list of taught subjects along with the number of hours recording. The first three subjects were taken in the first semester, while others were in the second semester. In most subjects, tutorial sessions were not recorded.

The on-line LCMS was started in parallel with the face-to-face mode of classroom teaching and each lecturer/instructor could freely determine how MOODLE was used in his subject. Each subject had a team consisting of two post-doctoral fellows responsible for restructuring and uploading non-video pedagogical material from the classroom lectures/tutorials and as well as enriching the on-line course by identifying and uploading additional resources from internet sources, links to documents or web pages from other academic institutions. The use of pedagogical content which includes text, external links, audio and video material may be considered as one of the techniques of addressing learners with different learning styles [10]. That is, regardless of individual learning styles (such as visual, auditory and sensory), each learner could find some appealing material from the LCMS.

For each taught courses, high definitions audio-video recordings of the various face-to-face classroom lectures were taken using several digital camera manned by non-academic staff. The raw recording files were subsequently post-processed (edited) and reviewed individually by the lecturers/instructors before they were encoded using the H264 digital video format and uploaded into a MOODLE LCMS. Course specific tutors were responsible for uploading supplementary materials including lecture notes, exercises and assignments, as well as, identifying suitable on-line simulations that were included as links. In total, over 350 hours of classroom lectures were captured and available in a MOODLE LCMS [12].

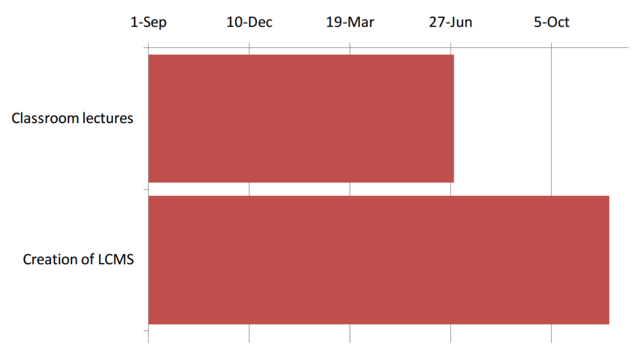

Fig. 4. Total duration of LCMS creation process

Fig. 4 shows the total duration it took to create the on-line (LCMS) content in relation to the academic session, which was only teaching and examinations without project work. As shown, the LCMS process was longer due to the need for post-processing of the video files and the requirement for each instructor to individually vet content of their video lectures, identify portions to be edited out and subsequently authorize the publication of the video file to the LCMS.

The sample population for the experiment consisted of 15 students and 12 instructors. Participation was optional and without prejudice. During the academic year, the participants were encouraged to report problems to the researcher and instructors were also encouraged to try other aspects of course management such as assessments. At the end of the academic year, random verbal interviews were used to obtain feedback from the participants: For over 70% of participants, this was their first experience with on-line learning platforms. Only two participants

(1 instructor and 1 student) reportedly found the context switching menu of the LCMS application strange to use: MOODLE tries to reduce end-user complexity by providing a consistent user interface while automatically adapting the menu items depending on the role of the individual user and the context of the activity being carried out. At least 1 instructor used the LCMS platform also for assessment. All participants were generally satisfied with the LCMS platform and the instructors were pleased as they did not have to reformat their existing pedagogical material for on-line use. The load from the additional on-line interactive was distributed amongst supporting tutors (post-doctoral fellows).

4.2 Experiment 2 Creation of off-line archive of LCMS

A different experiment was carried out to implement and study the technique described in section 3.2. Implementation began with the downloading of HTML contents using a free and open source web mirroring utility [21] that also performed some basic transformation of HTML links. The video recordings were obtained separately as files in a digital video format. While, the clean-up stage (see Figure 3) was automated using scripts that removed the search dialog-boxes and unneeded links, as well as, replacing the HTML code of the inbuilt video player of MOODLE by a thumbnail image (extracted from the video) that was used as a link to a regular HTML5 video tag; this allows learners to activate the video by pointing and clicking on the thumbnail. Also, where used, supplementary materials (additional resources) for the lessons were also downloaded if they were published with a suitable license.

Some additional material including copies of a HTML5 web browser were included within the archive and as well as additional HTML documents that explained how the off-line archive could be made available over an INTRANET or private network: Hosting the full archive or even a sub-set of it on an Intranet based HTTP server would make the pedagogical content available for use by all users on the local network. Final size was a 76GB portable archive containing over 350 hours of pedagogical material (video files, HTML files and additional documents) taken from the on-line LCMS and transformed for off-line use. Given the small size, individual learners can copy the entire archive or copy/download subsets of it for their personal/individual use.

The off-line archive was distributed to over 33 different educational institutions and in order to facilitate the maximal use of the archive, a subject specific lecturer/instructor as staff of the institution was given an introduction on how to use the of-line archive as part of active learning in the classroom. They were also encouraged to re-distribute or copy and/or even incorporate the contents into other products/projects within the boundaries of the creative commons license.

Apart from generally positive feedback received from all 33 institutions, a research study was used to acquire qualitative data at two of the 33 institutions that received off-line copies of the augmented LCMS. Both institutions were located in different countries to guarantee national, ethnic, lingual and cultural diversity, as well as, reduced possible effects/influences from variables such as common participants background, individual teaching methods, teacher/instructor, same department or institution. There were 154 random respondents in the questionnaire based study and participation in the survey was anonymous. Over 92% of respondents were learners and participants could choose to answer or ignore the various questionnaire items. A high standard of confidentiality was maintained as completed questionnaires were collected from respondents by the researcher or a designated local instructor in person. Table 3 provides a summary of results from the study.

Table 3. Positive responses to Survey items

Question	Percentage(%)
Do you frequently use your mobile device for internet access?	67.53
Do you regularly use e-learning platforms for study?	35.71
Do you regularly use on-line forums, etc?	44.51
Have the e-learning videos improved your understanding of classroom lessons?	74.03
Have you learnt new topics from the e-learning videos?.	71.42
Do you find studying with the LCMS platform easier than using paper based books and journals?	54.55

Table 3 shows that over 60% of respondents regularly use their mobile devices for internet access, while less than 40% regularly use e-learning platforms. Taken together both items suggest that education/learning is a strong reason why learners in developing countries visit the internet, which is an improvement compared to earlier reports [5]. The results in Table 3 suggest the efficacy of the augmentation techniques as over 70% agreed that the augmented e-learning platform improved their understanding of both classroom lessons as well as new topics they had not learnt. However, just over 50% found using the LCMS platform easier than paper based books and journals.

4.3 Discussion

In addressing the challenging burden of reformatting existing pedagogical content for on-line use faced by many STE instructors, this paper has presented the creation of lessons and materials for e-learning platforms from classroom recordings, carried out in a manner that mirrors the existing standards and criteria for face-to-face delivering of pedagogical content. The study shows that most of the participants agreed that the augmented e-learning platform improved their understanding of both classroom lessons, as well as, new topics they had not learnt.

Table 4 presents a comparison between classroom teaching and our LCMS platform augmented using the two techniques of recording of classroom lectures and off-lining of content. As show, both techniques ensures the pedagogical content of LCMS no longer require restructuring and may be used off-line.

Table 4. Comparision of classroom taught classes versus augmented LCMS

Item	Classroom teaching	Augmented LCMS
Leaner presence	Physical	On-line
Curriculum restructuring	No	No: thanks to recordings.
Internet required	No	No: thanks to off-line copy.

Some STE instructors suggest that it is difficult to adequately cover or introduces certain topics in lessons of short duration as is the regular practice in on-line video lessons. It was observed that the visibility of recording apparatus and cameraman within the classroom could become a source of distraction to the students during the lesson. Also, some one-on-one interactions between content providers (instructors) and the video editing staff were necessary during post-processing. In the 2nd experiment: when using an external tool for downloading/mirroring, it is important to specify options that could limit the downloaded objects by types or location and/or does not follow links to external resources. Also, the clickable image extracted from each video file could be improved by overlaying it with an intuitive playback symbol.

5 Conclusion

This paper presented two experiments on augmenting e-learning tools. The first was aimed at reducing the overhead associated with reformatting or adapting existing pedagogical material for use as learning objects for on-line courses. While, the second seeks to address the fundamental challenge of using on-line learning objects from resource constrained environments such as locations that lack adequate broadband connectivity.

The result obtained suggests the efficacy of the applied techniques in enhancing both self/personal and group learning as it was possible to create an on-live video (MOOC style) version of a face-to-face taught course that did not require reformatting existing pedagogical material. The integration of on-line simulations as equivalent for hands-on practical laboratory work into an e-learning platform is not seamless. Although, the augmented e-learning platform was used for personalized learning or by independent groups of learners, the involvement of a local (within institution) instructor(s) played a role in helping learners overcome difficulties and maintain focus. Feedback obtained suggest some benefit in learner comprehension and understanding from the independent (without instructors) use of the augmented e-learning platform.

The authors foresee future work involving the use and application of both techniques and are seeking funding to equip classrooms world-wide for capture devices, conduct an organized campaign to capture learning contents from leading instructors/content providers at national level as a viable way of improving national on-line content and finally, the creation of portable archives of existing community acclaimed world-class on-line academic programmes for world-wide distribution.

In conclusion, the work presented in this contribution suggest that an e-learning platform augmented by recordings of classroom lessons and on-line simulation tools can be used to move beyond the blended form of e-learning in STE disciplines, while the creation of portable USB archive may be used to improve the participation of learners from resource constrained environments.

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