EduPaL: Enabling Blended Learning in Resource Constrained Environments

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ABSTRACT

In developing regions, intermittent internet and high infrastructure costs are making it difficult to transit from assembly-line models of education delivery to effective technology enabled blended learning. This motivates the need for a low-cost system which can work with intermittent internet connection. In this paper, we propose EduPaL, a plug-and-learn solution which utilizes a low cost USB flash drive as a portable learning platform. Students can use the EduPaL client installed in the USB to download and consume educational content, including videos and quizzes. EduPaL tracks students' learning activities, and allows students to take notes and ask questions to the teacher. These learning activities are analyzed to create visualizations, in order to help teacher identify students, or topics that need more focus in the classroom. We conducted a semester long exploratory study with 30 students in an Indian university. EduPaL was found to be used by students at different times of the day and in different locations (hostel, home, lab), thus providing ubiquitous learning even without continuous internet connectivity. The teacher used visualizations to understand students' engagement, and inferred measures to improve student learning and video lectures.

Keywords

blended learning; flipped classroom; ubiquitous learning; ICTD; plug-and-learn; intermittent internet; USB-based learning platform

Categories and Subject Descriptors

K3.1 [**Computing Milieux**]: Computer Uses in Education- Computer-assisted instruction (CAI)

General Terms

Design; Human Factors; Experimentation.

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1. INTRODUCTION

The domain of education is undergoing a technology-enabled transformation in the developed world. Several forces are driving this change. There is a proliferation of high-quality digital content both through the rise of Open Educational Resources (OER) [4, 12] and Massive Open Online Courses (MOOCs) [6] available on the internet, as well as through commercial publishers who are striving to make their products more engaging and adaptive to learners. We see a greater use of technology for learning within classrooms and even outside the school. Recently, tablets and other personal devices, along with seamless network connectivity are making learning an anytime, anywhere activity. Blended learning, which combines classroom teaching with online learning activities, is being increasingly implemented by teachers. Extending this further, innovations in educational content delivery such as flipped classroom [26] that encourages learning outside the classroom and more hands-on problem solving time with the instructor inside the class, are being actively encouraged.

In deep contrast, education in developing regions continues to be plagued by basic problems. Lack of adequate IT infrastructure is a major challenge in the adoption of technology-enabled learning in developing regions. For example, educational models that require significant online activity are unlikely to be widely adopted in the near future in India, due to fragile and intermittent internet connectivity [5]. Cost is an important issue, since the expenses associated with a high-speed broadband connection may not be affordable to large sections of the population. Moreover, many students do not even own laptops/computers at home due to financial constraints. Thus, ubiquitous learning for all through seamless access to online resources is a distant dream for the developing regions. The work we report in this paper has been motivated by the need to increase access to quality digital content within the prevailing educational delivery models in developing regions like India. At the same time, the approach has been designed to be sensitive to ground realities related to intermittent internet connectivity and financial burden on the students.

In this paper, we present EduPaL, a plug-and-learn solution which utilizes a low cost USB flash drive as the main infrastructure component for learners. (Note: Apart fom the USB, access to a computer/laptop is also required to use EduPaL. Shared access to computer is easily available at school or home; and internet cafes across India provide access for as low as ~$0.15/hour). The USB drive acts as a client for the overall EduPaL system, and shall be referred to as 'EduPaL client' hereafter. The EduPaL client is prepackaged with all the necessary software for ease of use. The student simply plugs the USB drive into any computer, and whenever access to internet is available, the EduPaL client allows easy download of content (including video lectures and quizzes) from the EduPaL server. Once the content is downloaded, the student can access it even in the absence of internet. As the student watches the video content, the EduPaL client keeps track of how the video content is navigated, *e.g.*, where the learner is spending more time, which parts of the content s/he is skipping, *etc*. The client interface also allows the learner to take notes for self-understanding and to submit questions to the teacher. When the EduPaL client connects to the internet, complete student interaction history gets automatically transferred to the EduPaL server.

Rather than replacing teachers with technology, a key design goal of the EduPaL system is to keep teachers in the learning loop, by providing them control of the teaching process. Most of the institutions we engage with utilize Learning Management Systems (Moodle is the most predominantly used LMS), and their department labs are equipped with desktops/laptops with internet connectivity. One of the key pain points for teachers is that LMSs existing tools do not adequately capture the engagement of students. This motivated us to design the EduPaL system in a way that the teachers can track students' learning and engagement at a fine-grained level. These learning activities are analyzed to create visualizations for the teacher so that s/he can quickly understand which parts of the curriculum needs more focus in the classroom, or which sections of the video content needs to be improved to ease comprehension. Moreover, a teacher can view information at the level of each student so that personal attention may be given whenever possible.

To understand the usage of different features of EduPaL by students and teacher, we conducted a semester long exploratory study with 30 students at the Goa University, India. We found that the average video completion index is 69%. Students used EduPaL at different timings and locations, thus EduPaL enabled anytime anywhere access to educational content, even without continuous internet connection. The teacher used visualizations to understand students' engagement with videos, and inferred measures to enhance classroom teaching and video lectures.

2. RELATED WORK

Recently, efforts have been made by the Indian government to setup computer labs in educational institutions, and infrastructure to provide high-speed network across all Indian institutions (National Knowledge Network (NKN) [10]). This coupled with open educational resources (such as National Programme on Technology Enabled Learning (NPTEL) [11]) and relative ease with which digital content can be created by teachers [14] is resulting in tailored models of education delivery.

Video lecture based distance learning has been discussed for quite sometime [22], and the emergence of ubiquitous devices enable richer interaction and blended learning within and outside classrooms. The advent of MOOCs and OERs are enabling flipped classrooms to achieve greater interaction among students and teachers. Bishop *et al.* [13] presents a detailed survey of flipped education models; Strayer [35] provides a detailed comparison of flipped and traditional classroom in an introductory statistics course. While flipping the classroom seems to improve the learning outcomes [21, 33], the teachers do not have sufficient tools to implement this model effectively [35]. To elaborate, there are two main difficulties in implementing blended learning models, in particular, the flipped classroom model in developing nations like India - 1) lack of infrastructure and 2) lack of feedback for teachers.

2.1 Lack of Infrastructure

Lack of infrastructure for students, including computer and internet, is a major challenge in the adoption of technology-enabled learning in developing regions. Several researchers have proposed low-cost technological solutions for education, requiring intermittent to no internet [15, 25, 28, 24, 30]. Since DVD players are prevalent even among low income Indians, interactive DVDs as a platform to consume educational content has been proposed as a low cost solution [20]. Cellphone-based learning have been explored in offline and informal learning scenarios in resource constrained locations [27, 34, 31]. Kam *et al.* [25] presents a case study involving cellphone-based educational games towards English language learning in rural India. A follow-up work exploring unsupervised cellphone-based learning [27] shows that the impact of mobiles in learning is limited, and improvement in infrastructure (electricity) and social attitudes are necessary towards greater impact of technology-enabled learning in developing regions.

On the other hand, solutions working with intermittent internet connections have been proposed. Chen *et al.* [16] designed Contextual Information Portals (CIPs), to enable offline web browsing in educational context. Moore *et al.* [29] proposes a document search engine packaged in a USB drive to enable offline learning for mobile social workers. As 57.7% of rural India have access to internet at CSCs (government-sponsored Common Service Centers) for educational purposes [2] indicating that intermittent internet facilities can be leveraged for education. The challenges in such scenarios are to develop tools that enable learners to continue their learning in both online and offline mode. In this paper, we focus on learners in higher education with limited access to information and communication technology.

2.2 Lack of Feedback for Teachers

Feedback from students can help teachers to adapt their teaching styles and methods to suit the needs of their students [19]. Moreover, such feedback can help the teacher to take proactive or remedial decisions [32]. In learning management systems, such as Moodle and Blackboard, usage of educational content by students is often tracked at a fine granularity. Technology mediated education especially in distance and remote learning, allows easy tracking of learning activities, and enables teacher to understand the pulse of the ongoing class with pop-quiz, online chat forums, *etc.* [36, 37]. The proposed EduPaL system aims to keep the teacher in the loop during student's learning activities, similar in principle to the goals of BLOSSOMS initiative [7]. In EduPaL, students can provide explicit feedback during their learning process to help teachers towards tailoring their classes. Moreover, implicit interaction in terms of video viewing pattern is logged and analyzed by EduPaL to enable teacher identify student or content to focus on. In this paper, we explore the use of implicit and explicit interactions to enhance teacher's capability to tailor the class towards better outcome.

Recent work in Massively Empowered Classroom (MEC) [18], which enables MOOCs in engineering colleges in India is similar to our work. Both MEC and EduPaL cater to offline consumption of educational content in resource-constrained settings. Some of the key differences are: EduPaL collects feedback from students in offline mode. This feedback is analyzed to create visualizations for the teacher, enabling the teacher to understand their students video-viewing pattern and adapt accordingly. Another key difference is regarding the content used in the study. The course materials designed and used in our study are prepared by the teacher. This brings an amount of ownership, responsibility and control to the teacher, who is a key facilitator in student's learning process. This approach is different from MEC, where course materials were prepared by external experts. Finally, EduPaL's learning activity monitoring and content synchronization in resource-constrained settings seems novel.

3. EDUPAL LEARNING SYSTEM

As discussed, lack of infrastructure such as reliable internet and dedicated computers is a bottleneck for effectively implementing flipped classroom model in developing regions. Another challenge is the lack of feedback from students, as it is difficult for the teacher to monitor out-of-classroom whether students were engaged with the content prescribed to them. In this section, we describe our proposed learning system EduPaL, which uses a low cost USB drive based solution.

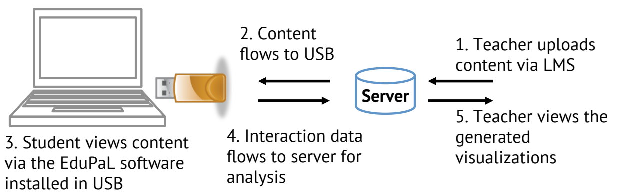

Figure 1: System Overview

Figure 1 shows overview of the EduPaL system. Teachers use a Learning Management System (LMS) to upload the lecture videos or quizzes. The LMS is accessed by the teacher using a web browser, under the assumption that teachers usually have access to good internet connection. In contrast, most students in developing regions lack access to a reliable internet connection, and in many cases, also lack access to a dedicated computer. To tackle these issues, every student is provided with a USB drive which is prepackaged with EduPaL software. The software synchronizes the content on the USB drive whenever an internet connection is detected. On the other hand, it allows the student to consume the content available on the USB even in the absence of internet. Irrespective of whether the internet is available or not, the student always consumes the content in an 'offline mode', that is locally from the USB drive. As s/he interacts with the content, the resident software on the USB tracks this interaction, which is later sent to the server to create visualizations for the teacher. We will now discuss each of the system component in greater detail.

3.1 EduPaL Client

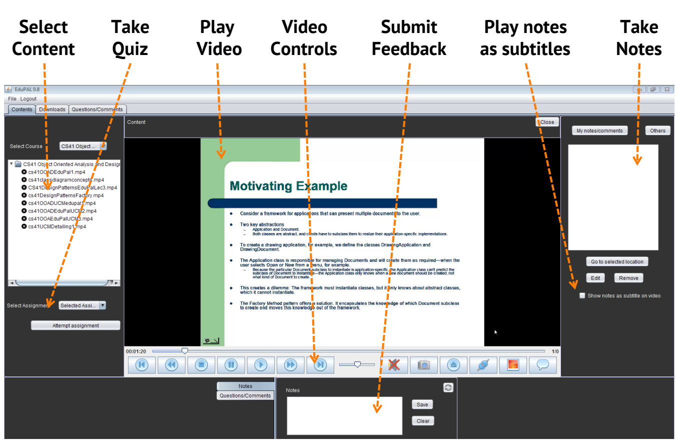

Figure 2: EduPaL Client

The EduPaL Client is installed on a USB drive, and can be used in an offline mode. Using the EduPaL client (Figure 2), a student can download and watch video lectures uploaded by the teacher, take notes for self-understanding, submit questions to the teacher, receive responses from the teacher, and attempt the quizzes.

In the current EduPaL system, neither the notes, nor the question answers are public due to privacy reasons. Also it has been observed in Indian classrooms that students are usually shy to ask questions [18], hence allowing EduPaL to be a public forum might deter their willingness to ask questions. One solution is to allow anonymous posting, but that could result in students posting irrelevant notes and questions, and requires moderation. Hence we decided not to have an open discussion forum. In the EduPaL system, whenever the teacher responds to a question asked by a student, both the question and the answer is shared with all the students, after anonymizing the student's name.

The client is built using Java Swing framework, and utilizes VLC media player plugin to enable video playback. Currently, the client is available on Windows operating system and since it is Java-based, with minimal efforts, it can be made available on Linux and other platforms. The client does not contain a bootable operating system, hence needs to be connected to a computer with functional operating system. We are also developing a mobile app (for tablets and smart-phones) with similar functionalities but is not covered as part of this paper. The client keeps a log of both explicit and implicit interactions. Questions submitted, notes taken by the student, and quiz submissions form the *explicit interactions*. On the other hand, *implicit interactions* comprise of various events recorded automatically by the EduPaL Client. Leveraging the events triggered by the VLC plugin, various interactions including play, pause, forward, rewind, moving the slider and mute are logged by the client along with the corresponding timestamp. This interaction data is stored within the USB by using the H2 Database Engine [1], which is a lightweight database with small memory footprint (3MB). This client database gets synchronized with the EduPaL server whenever internet is available, as described in section 3.3.

3.2 EduPaL Server

The EduPaL Server contains two main parts: a) Learning Management System (LMS) and b) Learning Activity Visualization.

3.2.1 Learning Management System (LMS)

Learning Management systems are widely used by faculty members in many universities. LMS's are mainly used to share content, conduct quizzes, and to submit assignments. One of our design goals while developing the EduPaL server, was to develop it as an LMS agnostic system, *i.e.*, to interface with any LMS for delivering content to students instead of binding to a specific LMS. We achieved this through the separation of LMS database from rest of the EduPaL server database, detailed in 3.3.

For the purpose of the deployment study, we integrated EduPaL with Moodle [9], which is a well-known open source LMS. While Moodle has portals for both teachers and students, we provided access to Moodle LMS only to teachers, as students are expected to use the EduPaL client for their learning activities.

3.2.2 Learning Activity Visualization

As mentioned earlier, the EduPaL client records several learning interactions of the students while they watch the video lectures or answer the quizzes. This interaction data is utilized to generate data visualizations for the teacher, so that s/he can get answers to questions such as: *What percentage of the posted video lectures were watched by the students? What percentage of a particular* *video lecture was watched by different students? Which portions of the video lectures were watched more than others?*

We now describe the different visualizations, and show how they help the teacher answer the above questions. Note that all the shown visualizations are generated from the data collected in the EduPaL Study (section 4).

Class Visualization.

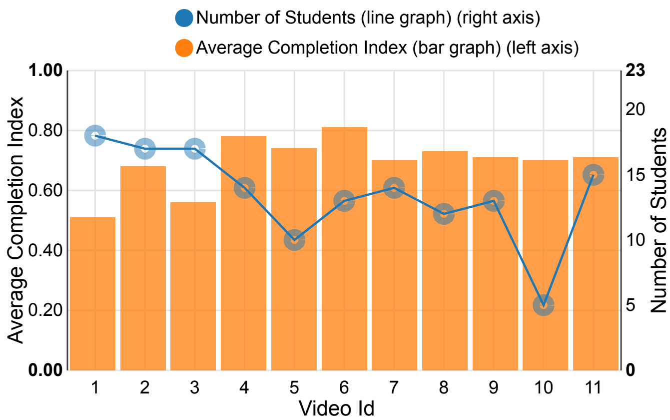

Figure 3: Class Visualization: Average completion index over all students per video (left axis), and number of students who played that video (right axis).

Figure 3 shows the Class Visualization. It shows aggregated information for the entire class and helps the teacher to get a summary of interactions by all the students, for all the lecture videos posted. We define *Completion Index* as the percentage of a particular video viewed by any student. *Average Completion Index* is the average of Completion Index across all the students who watch a particular video. In Figure 3, each number in the bottom axis represents a particular video (video name is displayed on hover over the video id). The left axis shows the Average Completion Index corresponding to each of these videos (orange bars), whereas the right axis shows the number of students who watched the corresponding videos (blue dots).

While the Average Completion Index gives the teacher an idea of *how much* of a particular video was watched on average, the blue dots show *how many* students actually watched it. As an example of why both of these metrics are required, consider video id-10. Though the Average Completion Index is close to 0.7, only 5 students played this video. On the other hand, though close to 15 students played the video id-3, the Average Completion Index is less than 0.6, suggesting that possibly very few students watched the entire video lecture. In this case, the teacher can perhaps infer that video id-3 was not very engaging and could improve the content.

Video Visualization.

The Class Visualization provides a summary of the complete class for all the videos. To get further insights, the teacher can drill down to a particular video using the Video Visualization. Figure 4 shows the Video Visualization for video id-3. The x-axis shows the student ids (name of student is shown on hover over a student id) and the y-axis shows the Completion Index for video id-3 for every student. As inferred from Figure 3, it can been observed that only a few students (6) watched the video lecture fully. This helps the teacher identify which student watched what percentage of the

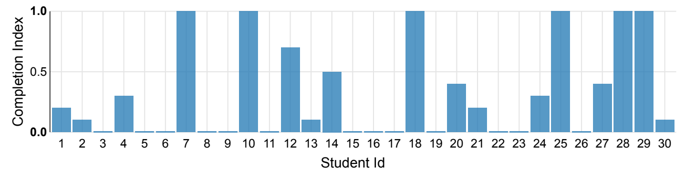

Figure 4: Video Visualization: Completion Index for video id-3

video lecture. For example, student id-12 watched about 70% of the video id-3. The teacher can send reminders or warnings to students who have not yet started watching the video, or who have not watched it fully, to ensure students go through the video before the classroom lecture. This information can also be used by a teacher to repeat any lecture material or make the students watch the lecture in the class, if s/he observes a poor Completion Index for majority of the students.

Similar to Completion Index, we define *Interaction Index*, that measures the number of notes taken and questions asked by a student while watching the video. The Interaction Index is shown for a particular video for all the students and is similar to Figure 4. For the sake of brevity, we skip discussion of the same.

Student Video Visualization.

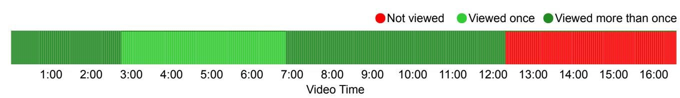

Figure 5: Student Visualization: Viewing details for video id-3 by student id-12, with portions not viewed (red), viewed once (light green), and viewed more than once (dark green)

The teacher can further drill down to know which portions of the video were seen (or skipped) by any student using the Student Video Visualization. Figure 5 shows the Student Video Visualization for student id-12 for the video id-3. Red portions of the video were not watched, light green portions were watched once, whereas dark green portions were watched more than once by this student. The teacher can hover on any portion of the video to view the corresponding topic name. Therefore, the teacher can infer which topics of the video were non-engaging. If many students find same topics to be non-engaging, the teacher can improve those portions of the video, or can revise it in the classroom lecture.

Note that mapping video portions to topics is currently done manually by the teacher using a simple tagging interface. However, we aim to automate this task in future by extracting speech from the video using IBM iTrans [3] in a textual form, and then analyzing this text to detect topics. This will reduce the load on teachers to manually tag topics for each lecture video.

3.3 Data Delivery

Figure 6 shows the Data Delivery mechanism of the EduPaL system. The two most important components of this system are the *server controller* and the *client controller*, as they regulate all the data flow between the EduPaL Server and the EduPaL Client. Any data exchange that happens between the server and client happens via these controllers using the HTTP protocol. There are three main data delivery flows in the EduPaL system: a. Catalog Flow, b. Content Flow, and c. Interaction data Flow.

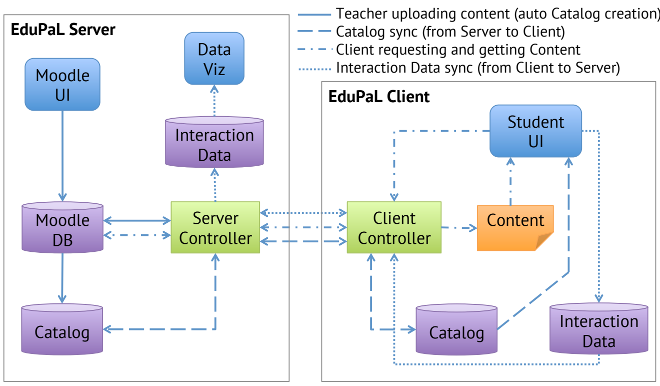

Figure 6: Data Delivery and Offline Content Viewing

Catalog Flow.
The teacher uploads content to the EduPaL server using Moodle's UI, and the content is stored in the Moodle File System. As mentioned earlier, we aim to keep our system loosely coupled with the LMS (Moodle in our case). Therefore, we store meta data of the uploaded content in EduPaL's catalog. The *catalog* is an index of all the content that is uploaded by the teacher to the EduPaL server. Along with the server, a copy of this catalog is also present in the EduPaL client. The catalog is the reference for the client to request any content from the server. Since EduPaL should work even with an intermittent internet connection, it is important that the server and client copies of the catalog are synchronized.

The server controller keeps a check on updates to the Moodle File System (*i.e.*, Moodle DB). Any such update triggers a script which exports content meta data from the Moodle File System to the catalog. A part of the content meta data is the file system path. Moodle stores content in paths which are created from their SHA1 hashes and hence full paths of the content are not directly accessible. As a workaround, we use Moodle's File API [8] to access the SHA1 hashes of the content. Once we have the SHA1 hash of any content, we generate its full path and store it in the catalog along with other content meta data.

Whenever the client is connected to the internet, every five minutes the client controller checks with the server controller for any updates to the catalog. The server controller sends the updated records to the client controller by comparing the last record id of the client catalog with that of the server. Finally, the student is able to view the available list of content using the Student UI. Note that file paths are not sent to the client for security of the content.

Content Flow.
Unlike the Catalog Flow which is fully automatic, a request to pull a particular content is manual and needs to be initiated by the student. The reason is to give the student control over *which* content s/he wants to download and *when* to download the content. This control is important in resource constrained environments, where bulky content downloads are costly. Once the student selects one or more content from the catalog, a request is sent by the client controller to the server controller for the transfer of files. The server controller fetches the content from the Moodle File System using the file path stored in the catalog, and transfers it to the client controller. The client controller stores the received content on the USB file system, and can be viewed by the student using the Student UI in an offline mode.

Interaction data Flow.
As described in section 3.1, the EduPAL client keeps a log of all the interaction of the students with the content. This interaction data has to flow to the EduPaL server so that visualizations can be generated and shown to the teacher. The client controller keeps a check on updates to the locally stored interaction data. It requests the server controller for the last record id of the server side interaction data, for the particular student. Using this id, the client controller forms an update file by selecting records from the client side interaction data that are missing from the server. The server controller accepts the update file, and updates the server side interaction data. Finally, the Learning Activity Visualization component utilizes the interaction data, as described in section 3.2.2, and show it in the Data Viz Teacher UI. Similar to catalog flow, this mechanism works automatically and does not require any manual input from the student/teacher.

4. EDUPAL STUDY

We conducted an exploratory study to understand usage of different features of EduPaL by students and teacher. The goal of the study was: a) to explore the use of EduPaL in a real-world deployment with intermittent internet access and non-availability of personal computers, and resultant outcome in learning and classroom participation, and b) to understand the use of teacher's interface in identifying students and topics which require more attention, and thus help in enhancing video lectures and classroom interaction.

EduPaL system was deployed for the CS41 Object Oriented Analysis and Design (OOAD) course at the Goa University, India. OOAD is a follow-up advance course offered to MCA (Masters in Computer Application) fourth semester students, who took CS33 Object Oriented Programming course in the previous semester. The course comprises of two weekly lectures on Tuesday and Thursday at 9-11 am. EduPaL system was deployed for the 4-months long semester, mid-Dec 2013 to mid-Apr 2014.

4.1 Participants

4.1.1 Students

Thirty students (7 female, 23 male, average age = 22.4 years, sd=1.04) took the OOAD course and hence participated in our study. All were in MCA fourth semester. Majority of the students (18) stayed in the University hostel, while 12 students stayed at home. Though all the students were from a low-income background with family annual income of ~0.5-1.5 Lakh INR[1], all except three has complete access to computer at their place of residence (remaining three have shared access to computer). Only 9 students had access to internet all the times, 8 students had intermittent access and 13 students had no internet at their place of residence. Students with internet access reported of bandwidth issues - only 2 students can watch online HD-videos, 6 students can watch low-quality online videos and remaining 9 students can only surf and send emails. All the students had access to internet at the University labs. Students reported using computer daily for 6.5 hours on average (sd=2.3), and internet for 3.3 hours (sd=2.2), including at home and University labs, mostly for understanding lecture, completing assignments and entertainment purposes. In addition, 8 students had previously enrolled for one or more online courses on Coursera and Udacity, however only two of them were able to finish the course. The major barriers reported by our students in completing online courses were that "*it requires good internet connection*", "*no instant clari-*

[1]One Lakh is 100,000 INR, or about $2,000

fication on doubts, unlike in classroom", "*high learning pace*" and "*no certificate*".

4.1.2 Teacher

One teacher (male, age=47 years) participated in our study. He has a Master's degree, and a teaching experience of 24 years. He uses computer to prepare lecture content and assignments, and spends ~6 hours on computer daily, including ~3 hours on internet. In particular, he uses Moodle heavily in his courses, and uses tools including Google Drive, Google Forms, Youtube, SlideShare, forums, blogs, and Facebook, to help with the teaching process. Previously, he has created video lectures for the software engineering course, but with the help of experts as part of a consultancy project. Similar to students, he reported of bad internet quality at the University and at his home, only allowing for low-quality online videos.

4.2 Study Design

To explore learning with EduPaL and compare it with the existing teaching methodology, the teacher agreed to conduct half of the lectures with the EduPaL system, and remaining half of the lectures without the EduPaL system (*non-EduPaL*). All Tuesday lectures were taught using EduPaL, while all Thursday lectures were non-EduPaL.

EduPaL lectures followed the flipped classroom model. The lecture videos for EduPaL were completely prepared by the teacher, including identifying content for the video, recording the video, dividing video content in different topics, integrating quiz at the end, and uploading and releasing it using EduPaL teacher interface. The teacher was required to release the video at least 24 hours before Tuesday's lecture. An email notification was sent to the students every time a new lecture video was released. The students were asked to watch the video using the EduPaL client, at least 2 hours before Tuesday's lecture. They were encouraged to use EduPaL to ask questions, take notes, and answer the quiz questions following the video.

The teacher was encouraged to use EduPaL teacher interface to understand video viewing pattern of the students. The teacher could identify portions of the video, which were viewed multiple times, viewed once, or skipped, by a student. In addition, the teacher could view quiz performance, answered questions asked by the students, and take note of any inference(s) derived from visualizing the video-viewing data. The teacher could also view data at a classroom level as well as at a student level. All of these actions were completed before Tuesday's classroom lecture. During the actual classroom lecture, the teacher discussed the video content and answered questions raised by the students in the classroom and in EduPaL.

Non-EduPaL lectures were delivered using traditional slides-based classroom teaching methodology. For these sessions, students were not asked to view any video before the classroom lecture. The teacher did not have any a-priori knowledge about the student's preparation for the lecture. The students asked questions, if any, in the classroom itself.

After each lecture, the teacher was asked to submit post-lecture survey, *i.e.*, feedback related to level of preparedness and level of participation of the students. This feedback was submitted for both with and without EduPaL-based sessions. Similarly, at the end of each lecture, students needed to fill a survey questionnaire about their understanding, level of interest and curiosity of the topic taught.

4.3 Procedure

One of the co-authors acted as a facilitator, helping the teacher to deploy and use the EduPaL system. The facilitator conducted a 2-hours training session with the teacher, and a 30-mins training session with the students, teaching them how to use the EduPaL system. The facilitator pointed out salient features of EduPaL, using an example learning video. As the facilitator and the teacher were geographically separated, the facilitator visited the deployment site twice, and guided the teacher over weekly telephone calls. Also, the teacher had on-demand telephone sessions with the facilitator in case of any doubt or issues. Note: The deployed EduPaL system was in the prototype-phase requiring bug fixes and feature upgrades, hence external facilitator support was provided to the teacher.

Apart from the data obtained by EduPaL system using implicit logging of student's video-viewing activities and explicit data input by students and teachers (including quiz, question, answers, notes, inferences, *etc.*), we also collected demography data and students previous experience with online courses, at the start of the study. In addition, to understand participants experience with EduPaL, at the end of the study, we conducted a survey with the students and an interview with the teacher. Finally, at the end of the semester, two exams were conducted – a subjective exam with 5 questions (3 questions were from the lectures taught using EduPaL, while 2 questions were from the non-EduPaL sessions) and an online objective exam with 18 questions (10 questions were from the EduPaL sessions, while 8 questions were from the non-EduPaL sessions). All the exams were prepared and graded by the teacher.

To summarize, these were the data points that we collected and used for analysis: student – demography survey, video lecture usage log data, quiz response, questions posted and notes taken, post-lecture survey, post-study survey, and end-semester subjective and objective exams; teacher – demography survey, teacher interface usage log data, answers posted and inferences taken, post-lecture survey, and post-study interview.

4.4 Equipment

Each student was asked to install EduPaL client on their personal USB drive.

5. RESULTS

During the whole course, a total of 24 lectures were delivered - 11 with EduPaL and 13 without EduPaL. The videos created by the teacher were of variable length ranging from 14.6 mins to 35.24 mins, with average length of 20.01 mins (sd=6.2). The teacher was asked to divide each video in separate topics, and provide the start time, end time, topic name, and difficulty level of each topic on a scale of 1-4 (1 being very easy to 4 being very hard). On an average, each video has 10 topics (sd=3.46). The mean length of each topic was 136.1 seconds (sd=73) and the difficulty level was 2.05 (sd=0.67).

After two weeks of deployment, we found missing data for 7 students, which were due to different reasons including loss of data as the EduPaL client software on USB got corrupted due to anti-virus solution on the connected computer. The problems were identified, fixed, and all the students were provided with a new version of EduPaL client during the fourth week. However, for consistency in data analysis, we analyzed data for only 23 students, for whom we had data for all 11 videos.

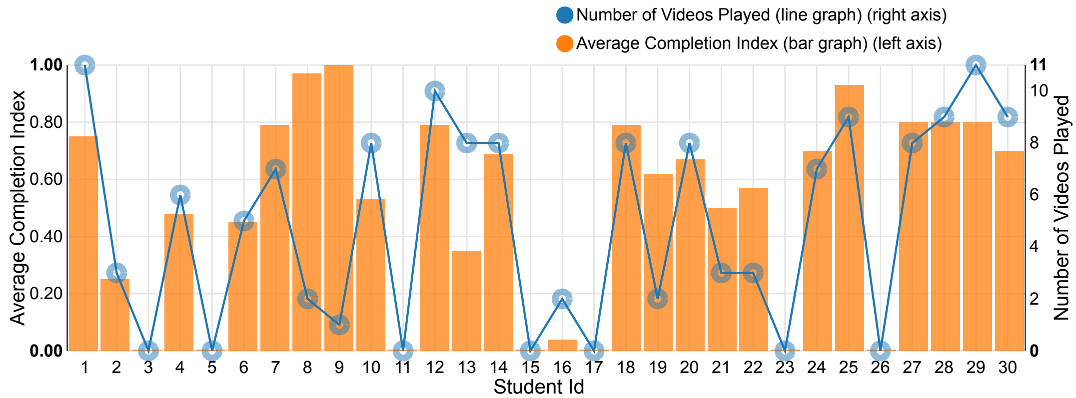

Figure 7: Average completion index over all videos per student (left axis), and number of videos played by each student (right axis). Note: Data for 7 students (student id-3, 5, 11, 15, 17, 23 and 25) is missing.

5.1 Anytime, Anywhere Interaction

5.1.1 Interaction with Videos

On an average, the 23 students played 6.4 videos (sd= 3.1) out of the 11 posted lecture videos; two students played all the 11 videos, while four students played 2 or less videos (Figure 7). For the played videos, the average completion index is 0.69 (sd=0.31). The first video (id-1) was played by maximum number of students (18), while video id-10 and id-5 were played by 5 and 10 students, respectively. This was mainly because video id-5 was released just the week before the exams, while video id-10 was released only 12 hours before the lecture (9 pm on Monday). On an average, a video was played by 13.45 students (sd=3.67) out of 23 students (Figure 3). Certain portions of the video were being watched multiple times (m=9.7%, sd=19.8%) (for instance, student id-12 playing portions of video id-3 multiple times, shown in dark green, Figure 5), may be to understand the topic better or because the student missed it while watching the first time.

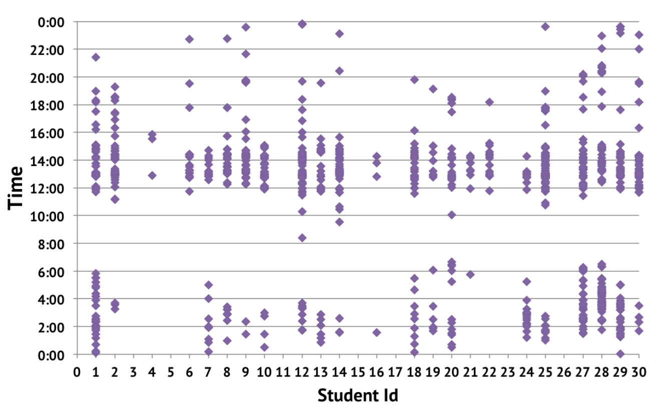

Figure 8: Time of usage of EduPaL by the students. Note: Data for 7 students (student id-3, 5, 11, 15, 17, 23 and 25) is missing.

The students identified ubiquity and low bandwidth usage as EduPaL's major advantage. In post-study survey with all 30 students, they mentioned that the best part of EduPaL is "*we can use it anywhere*", "*portable*" (6 students), "*anytime content*" (3 students) and "*it works without internet*" (7 students). Highlighting the ubiquity aspect, 7 students mentioned using EduPaL both in college and home, while 20 used EduPaL mainly in college and 3 used mainly at home. About the portability, 12 students accessed EduPaL using university labs computer, while 14 used their personal laptop/computer and 4 used both. In terms of usage, students used EduPaL at all hours throughout the day (Figure 8), with majority of them accessing the video during 1-4 pm, followed by 12:30-4 am. This highlights that the EduPaL system was able to achieve its goal of delivering content anytime, anywhere, irrespective of infrastructural constraints.

5.1.2 Interaction with Teacher

Analogous to classroom lecture, interaction between teacher and students in the form of question-answers is enabled using EduPaL. Students can submit questions to the teacher using EduPaL client interface. Many students mentioned asking question (13 students) to be a crucial feature. While watching lecture videos, students can also take notes for self-understanding using EduPaL interface, similar to classroom lecture. Figure 9 shows the timeline of when

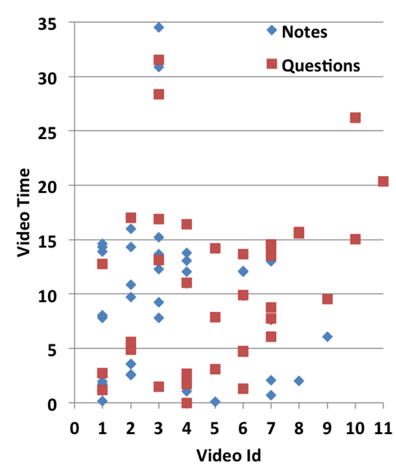

Figure 9: Student's questions and notes with respect to video timelline.

questions questions were asked and notes were taken with respect to the video time. The questions and notes timing are uniformly distributed across the video length.

Questions and Answers: Twelve students posted 37 questions (m=3.1, sd=2.9) using the EduPaL interface with student id-1 asking maximum of 12 questions. Each video received one or more questions. Out of the 37 questions, the teacher answered 11 questions using EduPaL interface. The low number of answers by the teacher was mainly because the question required an elaborate response suited for classroom (*e.g.*, "*How to think in objects effectively?*"), the topic raised in the question would be covered in future lecture (*e.g.*, "*What is delegation? What is the functionality of delegation? When we can use delegation in program design?*"), or the question was not legible ("*Say a system unexpectedly shuts down are exits between a job. Can/Does this need to be modeled in a use case diagram?*"). The questions which were responded to by the teacher were made public (after anonymizing it), along with the answers.

Notes: Eight students took 47 notes (m=5.9, sd=3.6) using the EduPaL interface, with student id-30 taking a maximum of 12 notes. Most of the notes were comprehensive, such as "*Generalization is a kind of relation*", "*Aggregation is a stronger form of association*". The notes were automatically linked to the portion of the video, where the user started taking the note.

We enquired with the teacher regarding low participation in posting questions and taking notes on the EduPaL client. The teacher mentioned that "*there are only 8 to 10 active students in the class*", and they were the ones who were actively using the EduPaL client.

5.2 Teacher with Control

EduPaL provides flexibility to teachers to control the classes as per their needs. In our study, the video creation was completely handled by the teacher, so that the teacher has complete control over the content. The teacher appreciated the EduPaL's teacher interface, particularly the "*ability to answer student's questions*", "*heat map and other visualization*", detailed video access information about who accessed video when and how often, and quiz data.

Previous research [35] has identified challenges in implementing flipped classroom teaching model. One of the major reported barriers is that all the students are required to watch the video lecture before coming to the class. Even during our EduPaL deployment, for one of the lectures, the teacher noticed using the EduPaL teacher interface that only 5 students have played the video prior to the lecture (Figure 3). In order to solve the situation, the teacher asked the students to watch the video during the first 30 minutes of the class. Thus involving teacher can help overcome some of the shortcomings of flipped classroom model.

Based on the different visualizations, the teacher was expected to make inferences and come up with a plan of action (PoA). In total, the teacher noted 10 inferences, and respectively 10 PoA. Some inferences were "*very few students have completely watched videos*", "*very few questions*", and accordingly the plan of action were "*smaller videos and uploading well before time may help in improving the completion rate*", "*develop videos to enable students to ask questions*", respectively.

5.3 Learning

For the *end-semester subjective exam*, we normalized the data and conducted a paired-samples t-test. We found that students performed significantly well in questions asked from EduPaL sessions (m=4.1, sd=2.17, out of 10 marks), compared to questions from non-EduPaL sessions (m=1.17, sd=1.1), with t_{29}=8.8, p<0.001. This is in accordance to previous research claiming that a flipped classroom model results in more learning [33]. However, this could also be attributed to the fact that the number of hours spent for pre-class preparation by the students was higher for EduPaL sessions compared to non-EduPaL sessions, in accordance with the flipped learning model. Moreover, post-lecture student survey data showed that the level of participation, level of interest, and level of understanding of the topics taught (on a 4-point Likert scale) was higher for EduPaL sessions (m=3.4, sd=0.4) compared to non-EduPaL sessions (m=2.6, sd=0.6), however it was not statistically significant. This may be the reason for students scoring higher marks for questions from EduPaL sessions.

For the *end-semester objective exam*, though we did not find any statistically significant difference between EduPaL (m=7.34, sd=1.4, out of 10 marks) and non-EduPaL (m=6.64, sd=2.4), the minimum marks scored were 5 (out of 10) for EduPaL session related questions and 1.25 (out of 10) for non-EduPaL. This data hints that even the poor performing students, performed better with EduPaL. In terms of time taken to complete the objective online test, EduPaL questions (m=7.75 mins, sd=4.9) took less time compared to non-EduPaL questions (m=16.25 mins, sd=8.6), with t_{29}=4.6, p<0.001. This hints that students were faster in answering objective questions from EduPaL sessions.

Out of the 11 videos, 5 videos had a quiz at the end of the video. Each quiz consisted of five multiple-choice questions (MCQ) of 1-mark each with no partial marking. The remaining three videos had elaborate subjective questions or coding exercise as assignment. In total, 308 questions responses were received, *i.e.*, on an average, 12.6 students (sd=2.4) attempted the 5-question quiz per video. The students scored high on quiz, with an average score of 3.45 (sd=1.45) per quiz, and took 67.1 seconds (sd=115.7) on average, to answer a quiz question. The students were aware that the marks obtained in the quizzes would not be used for final grading. Irrespective of that, we observed medium participation in quiz, which is in contrast with previous research in Indian context where in students were found to study only to score well in exams [18]. We did not find any correlation between amount of topic viewed by a student and response to the quiz question related to that topic, though we found weak inverse correlation between amount of topic viewed and time taken to respond to the related quiz question, with Spearman's $r(306)$=-0.25, p<0.01.

5.4 Educational Video Creation

Previous research has identified that creating video lectures is challenging for teachers. Some MOOCs platform uses experts to create high quality videos [17]. Majority of students (six out of eight) who have previously enrolled for MOOCs mentioned that "*high video quality*" attracted them towards the online courses. However, such videos were hard to understand for the students, due to the non-Indian English accent, which has also been previously reported [18]. In a resource-constrained setting, it is hard to get an expert's help. Hence, we asked the OOAD course teacher to create videos for the EduPaL study. The other reason was that we wanted the teacher to have full control over the content. The teacher received feedback about the video content implicitly from students' video-viewing pattern and explicitly from post-lecture survey filled by the students. Two students mentioned that they liked the content, as it "*was custom made for us*". Based on the video-viewing pattern, the teacher inferred the quality of the video, and steps to be taken to improve the quality.

For instance, the first three lecture videos posted by the teacher were 25.35, 17.6 and 35.14 mins long, respectively. Using EduPaL visualization, the teacher inferred that majority of students were dropping out at ~16 mins. Thus he decided to create videos of length 16 mins or shorter. This is in accordance with existing literature [23]. Moreover, the students complained about audio quality and lack of examples in the videos. This led to the teacher using a closed silent room at home to record audio for the videos, and add more examples to the content. Hence such quick implicit and explicit feedback can help teachers to create more consumable content.

For the study, the teacher was explicitly asked to create all the education content including videos. As content creation can be challenging, the teacher can upload relevant and appropriate learning material from the internet, including youtube or other MOOC videos, which students can watch using the EduPaL client.

6. DISCUSSION

Based on our experience from the EduPaL deployment study, we propose design recommendations for developing low cost educational technologies for blended learning.

6.1 Design Implications

Anytime, anywhere content was the key feature that students liked in EduPaL. In resource constrained environments, a delivery model similar to the one we used in EduPaL could be useful. This delivery model synchronizes the content catalog automatically, however, gives the user control on which content to download and when. This could be crucial in environments where bulky downloads are costly.

In the current state-of-the-art MOOCs, implicit data collection from video watching, and feed back the data to adapt content and improve student engagement seems to be missing. Video viewing pattern can help in identifying disengaged students. It can also help in identifying non-engaging topics in a video lecture, thus providing feedback to the instructor with respect to content creation. In our work, we showed the interaction data to the teacher using different visualizations, and asked them to infer and develop a plan of action. This log of teaching activities can be analyzed for best practices to be adopted in future teaching sessions and also as a teaching support knowledge base for new teachers and in training.

Keeping the teacher in control of the class while using EduPaL worked well in terms of learning and with respect to video adoption rate. As we noted in one instance, the teacher asked the students to watch a particular lecture video in class when he found using the interaction data visualizations, that very few students had watched the lecture prior to the class. Therefore, keeping the teacher in the loop while adopting such technologies would be beneficial, especially when the students are not self-motivated.

EduPaL has a feature to automatically share questions which were responded to by the teacher after anonymizing the student who asked the question. This was done to reduce inhibitions among the students in asking questions. Such an approach might work well where a middle ground between sharing and privacy has to be struck.

Students liked the feature to play notes and questions with the portion of the video where the note/question was recorded. When the student played the video, EduPaL showed the notes s/he had previously taken in the form of subtitles at appropriate times in the video. This way, the student is not overwhelmed with all the notes for a particular video. While asking certain questions, students referred to portions of the video where they were asking the question. Similar to notes, even questions were automatically linked to the portion of the video where the question was asked. This proved helpful to the teacher.

6.2 Limitations

As it was a real-world deployment in a developing world, there were certain limitations. First, as per the study design, the teacher was not able to release a new lecture video every Tuesday, due to exams, college events, complete internet shutdown in the college because of natural disaster, or gateway to LAN crashing. Hence even for a four month course, we only have data for 24 lectures. Second, the EduPaL classes were always delivered on Tuesday, while non-EduPaL classes were delivered on Thursday. Ideally the classes should have been balanced across days. However in spite of our request the teacher did not agree to it, to avoid confusion among students. Third, learning benefits with EduPaL have a significant confound, as the students spent considerably more time preparing for EduPaL classes. Hence, it is not clear if the learning was only due to EduPaL, or due to a greater amount of preparation being assigned by the teacher. Finally the results are based on limited data collected from an initial exploratory study with EduPAL for one course. In future, a controlled study is required to better understand the benefits and shortcomings of EduPaL.

7. CONCLUSION

In this paper, we presented our experience with designing a low cost ubiquitous device to enable blended learning in resource constrained environments. State-of-the-art blended learning solutions require continuous access to internet, or continuous access to a computer with pre-installed software and logins for each student. Due to high cost, dedicated and continuous access to computer and internet is a challenge in developing regions like India. The ease of deployment and low-cost USB device seems to be a right choice until mobile tablets and 3G connectivity are affordable among students. Also, implicit and explicit feedback from student's interaction, and control to the teacher to plan and adapt face-to-face sessions shows improved performance among students. In this paper, we also presented initial attempts on providing insights to a teacher about student's questions and student engagement through the captured learning activity information. Such fine-grained monitoring of learning activities and utilizing them towards measuring student engagement and aiding classroom interaction seems to be novel.

We plan to extend the EduPaL system based on the field study experience. We are working on developing a mobile app client while reusing the server infrastructure to allow learning through mobile and tablets. We also plan to have additional teacher support tools to seamlessly plan and execute blended learning activities.

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