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Satellite-Based Interactive Distance Education: A Scalable and Quality Learning Model

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Abstract

The dissemination of high quality education to a large number of geographically spread participants is a growing need in many countries. The Indian Institute of Technology, Bombay, has successfully deployed a novel satellite-based model of a Distance Education Programme (DEP). The key objectives of the DEP are not only to impart quality education to a large number of participants but also to provide a live two-way interactive classroom environment. The feedback from the participants shows that the DEP has been very effective in enhancing the expertise of a large number of working professionals as well as teachers from other engineering colleges. In this paper, we discuss the key features of the DEP – interactivity, scalability and reusability – and give a comprehensive report of a three-year study on programme. We discuss the underlying economics that arise out of scaling such a programme and present the current status of the DEP. We believe that the live interaction with faculty members and peer-to-peer interaction among participants that is provided by the DEP greatly enhance the effectiveness of distance learning. We feel that such a model can be easily adopted by other institutes elsewhere.

Abstrak

Penyebaran pendidikan berkualiti tinggi kepada bilangan peserta yang besar yang tersebar luas secara geografi merupakan keperluan banyak negara. Indian Institute of Technology di Bombay telah berjaya melaksanakan model program pendidikan jarak jauh berasaskan satelit. Objektif-objektif program ini bukan saja untuk memberikan pendidikan berkualiti kepada bilangan peserta yang ramai tetapi juga untuk menyediakan persekitaran bilik darjah interaktif dua-hala secara langsung. Maklum balas yang diterima daripada peserta menunjukkan bahawa program ini telah berkesan dalam mempertingkatkan kemahiran bilangan profesional bekerja yang ramai dan juga guru-guru daripada kolej kejuruteraan yang lain. Dalam kertas kerja ini kita membincangkan ciri-ciri utama program pendidikan jarak jauh - interaktiviti, skalabiliti dan

kegunaan semula - dan memberikan laporan komprehensif kajian tiga tahun program ini. Kita membincangkan asas ekonomi yang menyumbang kepada penawaran program ini dan membentangkan status masa. Kita percaya bahawa interaksi secara langsung dengan pensyarah dan interaksi sesama pelajar yang disediakan oleh program ini mempertingkatkan keberkesanan pembelajaran jarak jauh. Kita merasakan bahawa model ini boleh disesuaikan oleh institusi-institusi lain.

Introduction

In developing countries, although numerous qualified engineers graduate every year, there is a vast gap between the resources required and the professionals available in any field of the industry (Krithivasan, 2003). Typically, there is also a need to upgrade the expertise of the teachers in the regional institutes, as this has a direct impact on the quality of education across the country. Hence, the dissemination of high quality education to a large number of geographically spread participants is an important and challenging problem (Baru et al., 2004).

In 2002, the Indian Institute of Technology, Bombay (IITB), one of the premier institutes in India, took up this challenge and successfully deployed a novel model of a Distance Education Programme (DEP). The objectives of the DEP are:

- Imparting education by the transmission of IITB courses to a large number of participants.
- Creating a live two-way interactive classroom environment for the participants.
- Deploying a scalable solution to reach an increasing number of participants across the country.
- Providing a cost-effective solution for the participating centres in terms of affordable technology and minimal recurring charges.

The DEP uses a satellite-based (VSAT) network with IITB as the transmitting centre from where the lectures originate. IITB is connected to several receiving remote centres (RCs) across the country. The DEP uses a 512 kbps bandwidth dedicated broadcast data channel and 16 kbps point-to-point control channel. Through the DEP, the remote participants have

live and synchronous access to teaching materials provided by the IITB faculty members (Krithivasan & Iyer, 2004). The feedback from the participants shows that the DEP is a boon for working professionals, students and teachers across the country. In this paper, we present a comprehensive report of a three-year study on the DEP. We discuss the key features of the programme, its scalability and economic viability. We feel that such a model can be easily adopted by other institutes elsewhere.

Distance Education Models

Distance education provides a great deal of flexibility and is a preferred mode of learning for students and working professionals who are unable to attend full-time colleges. Furthermore, distance education through open universities (OU) is the most preferred way to meet the ever-increasing demand for quality education in remote areas in developing countries. There are several models of distance education. These can be classified into four major categories:

- The traditional model
- The web-based model
- The Internet streaming model
- The satellite broadcast model

A detailed discussion of each model is beyond the scope of this paper. In the following sections, we provide a brief discussion of each model and justify our selection of the satellite based model for the DEP.

The Traditional Model

Before the advent of the Internet, distance education was provided mainly through the despatch of course contents by mail. This can be termed as the traditional model. Even though minor variations exist, usually in this model, geographically dispersed students register with an institute/ university. The interface between students and institute is called a study centre. Study centres are established at various locations and students can attend limited interactive sessions at these centres. The students appear for the periodic examinations conducted by the institute/university and are awarded degrees/certificates after evaluation. This is a viable model for

distance education in developing countries as the costs involved are low, both for the institutes/universities as well as for students. However, the drawbacks of this model are that the students do not have a day-to-day live interaction with the faculty members. The peer-to-peer interaction is also reduced which might result in a decrease in the effectiveness of learning.

The Web-Based Model

Ease of Internet access has led to the setting up of online education portals by many universities across the globe. We term this the web-based model (Khalifa & Lam, 2002). In this model, an institute/university announces a number of courses for which the students can register. These students have access to course contents (slides, notes) through the Internet. They appear for periodic online examinations for the purpose of certification. Such a model provides access to "education anytime, anywhere" and has proved to be useful for working professionals. The main prerequisite for this model is that every student should have his/her own computer and good internet connectivity to access the course contents. This model is, however, not very suitable for distance education in developing countries where the personal computer penetration levels may be very low, and the cost of implementing such a model may be very high. Another drawback of this model is the missing element of classroom environment and lack of peer-to-peer interaction within the student community.

The Internet Streaming Model

Streaming is a method of data transfer in which a multimedia file can be viewed while it is being downloaded. The advantage of streaming is that it does not require local storage of the entire multimedia file and can also support real-time access to live events. We term this the internet streaming model (Latchman, 2001). The four major steps involved in streaming are:

- choosing the format
- encoding the content
- storing the content
- delivering the content to the client media player

The streaming model can be implemented in three ways: live streaming, on-demand streaming and simulated live streaming (Krithivasan & Iyer, 2004). In live streaming, the live feed from a lecture is encoded in the file and is relayed to a streaming server. In conjunction with the web server, the streaming servers uses one of many protocols, like HTTP or RTSP, to serve the file over internet to the participants. In on-demand streaming, the video files of a lecture are encoded off-line at various bit rates and stored in the streaming server. The participant has the option of choosing the appropriate encoded video, based on the bandwidth available. This mode also offers participants the flexibility to pause/replay the files as well as access them at any time and from any place. In simulated live streaming, the files are stored in the streaming server but start streaming only at predetermined time slots. Hence even though a lecture is not live, all participants have to log in to the session synchronously and do not have the flexibility to view it at their own convenience. Simulated live streaming attempts to capture a traditional classroom effect, where the groups of participants are required to view the lecture videos synchronously, even though they might be geographically dispersed.

Using this model, a university typically augments the course video streams with an online support system that provides functionalities like a whiteboard, messaging and chat facilities to the participants. While internet streaming is a flexible model, it requires a reliable and dedicated minimum bandwidth for good quality reception. The availability of the bandwidth is often a major constraint in reaching remote areas in developing countries.

The Satellite Broadcast Model

The satellite broadcast model has a source centre where the content originates and is transmitted to various remote centres using a VSAT channel. The five major VSAT delivery mechanisms are:

- One-way data transmission
- Two-way data transmission
- One-way audio/video transmission
- One-way video, two-way audio transmission
- Two-way audio/video transmission

This model has many significant advantages like the unlimited reach even to remote locations, reliability, fast deployment and low set-up costs, easier network management and maintenance. This model also allows for incremental expansion to large numbers of remote centres. Additionally, bandwidth costs can be amortised over the number of centres. After weighing the pros and cons of various models with respect to our objectives, the satellite broadcast model with the two-way audio/video delivery mechanism was selected for the DEP implementation. In the next section, we will describe the various features of the DEP model.

The DEP Model

The Distance Education Programme (DEP) at IITB uses a satellite-based network. It consists of a central transmitting site (IITB) and a number of geographically dispersed remote centres (RCs) receiving the transmission, synchronously.

The DEP Network

The DEP network as shown in Figure 1 has a high bandwidth [512 kbps], half duplex, broadcast data channel and a low bandwidth [16 kbps], full duplex, point-to-point control channel. The network consists of nodes at IITB as well as at various RCs. The 512 kbps channel is a Demand Assigned Multiple Access (DAMA) channel and only one centre can use it for data transfer at a time (Pratt & Bostian, 2002). Other centres remain in the "receive" mode when the station having control of the 512 kbps channel transmits. The 16 kbps full duplex channel is a Time Division Multiple Access (TDMA) channel and is available for data transfer at all times to all the centres in the network (Pratt & Bostian, 2002).

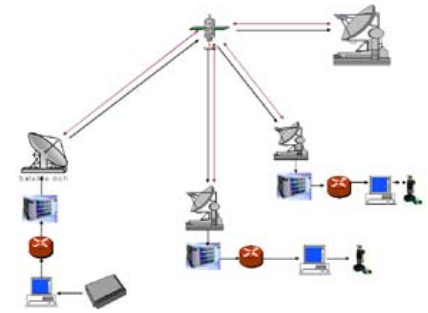

Figure 1 The DEP Network

The network at the central site has a large 3.8 metre antenna and a small 1.2 metre antenna separately for the data and control channel. The computer used for starting the multicast at the central site encodes the signal to an H323 format before sending it out for transmission. The equivalent receiving computer at the RC decodes the signal. At both the central site and the RC, the signals are routed through an up/down converter, a chassis, a router and an indoor unit. Figure 2 and Figure 3 illustrate the set-up at the central site and the RC.

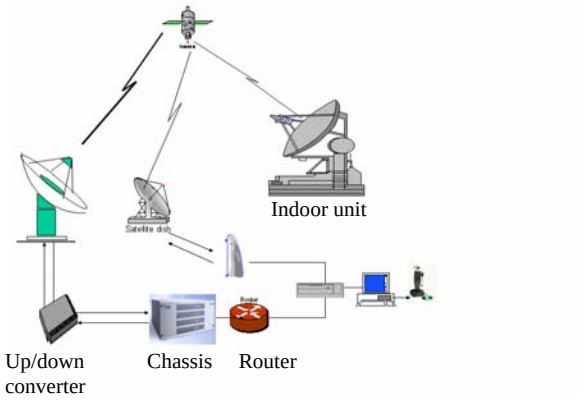

Figure 2 The IITB Network Set-up

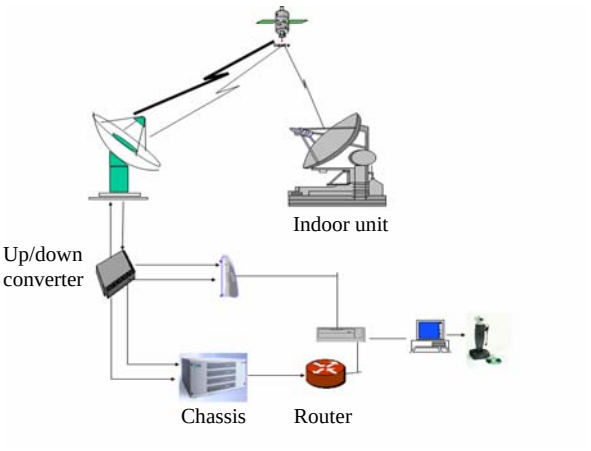

Figure 3 The RC Network Set-up

The DEO Operations

The workflow involved in offering a course through the DEP is as follows:

Pre-course activities

At the commencement of every semester, the courses offered are announced by advertising on the DEP website, through local newspapers and notifications to all engineering colleges. In consultation with the faculty members, the schedules are announced, the course notes are created and prepared for distribution. The registration of participants is done using an indigenously developed online software "Tejas" (Vijayalakshmi, 2003) shown in Figure 4. The participants are given a window of two weeks to add/drop courses. The course home pages are made ready with resources, announcements, contact details and course schedules as shown in Figure 5.

Figure 4 Online registration using Tejas

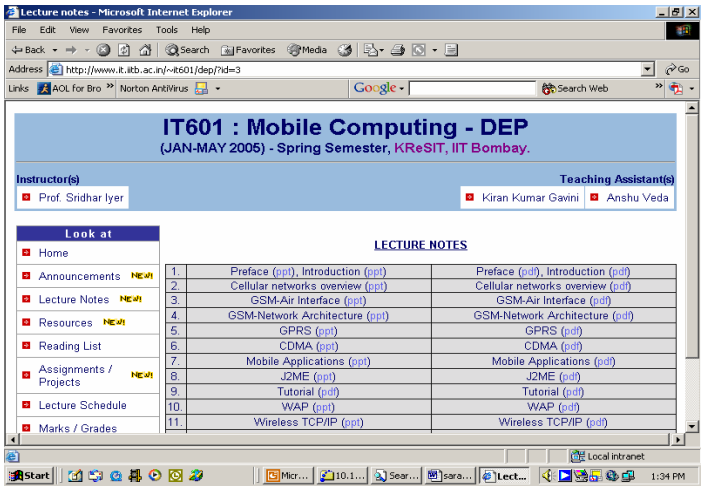

Figure 5 A sample course home page

During each lecture:

- The faculty gives the lectures in a state-of- the-art studio cum classroom, as shown in Figure 6. The faculty has the option of using slides, the whiteboard and multimedia clips to deliver the lectures.
- The multiple audio and video feeds from the faculty members, the whiteboard, local and RC participants are all mixed in real-time by using online audio video mixers. A single audio-video feed is then transmitted to all RCs through the VSAT network. A block diagram of mixing is shown in Figure 7.
- These lectures are now synchronously transmitted through the high bandwidth data channel of the DEP network to the various registered RCs, where the lectures are projected onto a large screen.
- A classroom scenario at each RC has thirty to forty students viewing the lecture. A participants from any of the RCs has the freedom to ask a question during the lecture. This request is communicated to the faculty member through the low bandwidth control channel.
- The faculty member may grant the floor to the RC, in which case the high bandwidth data channel is transferred to the RC for uplink. The question being asked is heard by the faculty member as well as the participants at all the other RCs. Subsequently, the floor is taken back by the faculty member, the question is answered and the lecture continues.
- The faculty member can also invite participation from the RCs, by granting the floor independently.

Figure 6 A typical classroom session

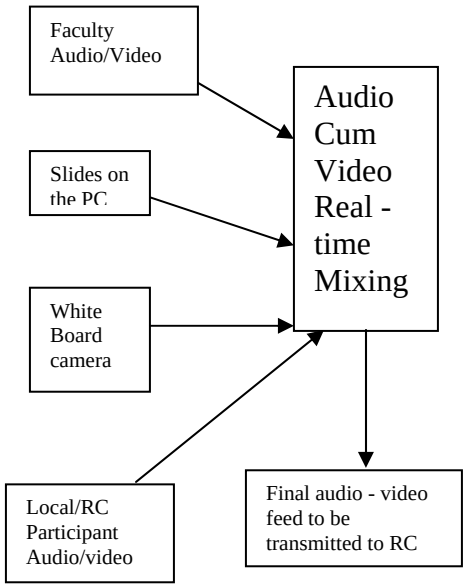

Figure 7 Real-time mixing of audio/video materials

Course Support Activities

A team of teaching assistants (TAs) provide the required support to run a course smoothly. The TAs maintain the course home pages, make regular announcements, upload necessary resources, conduct tutorials, announce assignments, upload marks, provide off-line support through email, FAQs and respond to periodic feedback from the participants.

Evaluation

Conducting examinations across distributed RCs is a major challenge. The examination question paper is password protected and mailed to all RCs. The password is sent to the RCs just one hour before an examination begins so as to allow them to make copies. The answer booklets are then dispatched to the DEP and are graded centrally at IITB. The faculty members are available during the examinations at the central site. All examinations are monitored by the central site through the DEP network.

The End of the Course

The lectures which are recorded during the course are captured, edited and archived on various media like CDs, DVDs and DV tapes. The archival materials can be reused, and can also be used for reference by faculty members and participants in the future. In the event of any transmission problems at any RC, a set of CDs for that particular session is sent for the benefit of participants at that centre.

The DEP Administration

The DEP administration operates at two levels: core functions at the central site and distributed functions at the RCs. The core administration functions are the following:

Programme management
This includes activities like programme planning and scheduling, coordination with service providers and RCs, programme expansion planning, registration, data processing, report generation and accounts maintenance.

Studio management
This includes activities like ensuring the trouble-free transmission of lectures, continuous testing and maintenance of studio equipment, upgrading infrastructure as and when needed, and interaction with service providers for customer support.

Content management
This includes activities like content despatch to all RCs, coordination with faculty members and RCs, despatch of CDs to RCs in the event of transmission failures, editing lectures and transferring of contents to CDs, DVDs, DV tapes for archival storage.

The distributed functions at each RC include the following:

- Marketing courses through counselling and local announcements and displaying promotional materials.
- Registration of participants and maintenance of their records.
- Mentoring and tutoring of the participants during the course.

- Conducting examinations and despatching answer sheets.
- Maintenance of the infrastructure used at the RCs and coordination with service providers.
- Continuous coordination with the central administration team.

The administration process has been streamlined across RCs by using an indigenously developed software named "Tejas". Tejas was developed keeping in view the unique requirements of the DEP. The registration module is accessed by all the RCs to enter the participant's data. The other modules such as the faculty module, student module, report generation module, etc., help in the online integration of all activities. Tejas also allows the central site to monitor the status at each RC on a daily basis. In the next section, we discuss the key distinguishing features of the DEP.

Key DEP Features

The key distinguishing features of the DEP are: live synchronous lectures with interactivity, technical and administrative scalability and content reusability. We discuss each of these below:

Interactivity
The DEP model provides a live classroom experience to participants at the RCs. As explained above, the DEP uses a one-way high bandwidth data channel and a two-way low bandwidth control channel. So, when a participant wants to ask a question, the request is communicated to the faculty member through the low bandwidth control channel. When the faculty member grants the floor, the high bandwidth data channel is transferred to the RC. Subsequently, the faculty member takes the floor back and answers the question.

The two-way audio video communication between the central site (IITB) and the RCs adds tremendous value to the programme. As the transmission is synchronous, live and interactive, the model provides a live classroom environment for the participant.

Scalability

In order to make the DEP available to large numbers of geographically dispersed RCs, the scalability of the technology as well as administrative processes is necessary. We examine each of these below:

- Technology: the DEP uses a satellite-based (VSAT) network, which is inherently scalable and reliable. This makes the learning experience consistent across the RCs. As the satellite coverage extends throughout the entire country, expanding the programme to include an RC in any part of the country is relatively simple. A new RC needs to install only the VSAT receiving infrastructure to receive the transmission from the central site.

- Administration: the DEP administration happens at two levels – core functions at the central site and distributed functions at the RCs. The distributed administration and logistics management at the RCs simplify the processes of student management and coordination, thereby resulting in the scalability of the programme.

Reusability of Contents

The lectures, including the interaction with the RC participants, are recorded, edited and archived on data CDs, DVDs and DV tapes. These are not only available to the faculty members for future reference but can also be used for subsequent retransmission of the courses. Based on this idea, an extension model was implemented successfully.

In the next section, we present the responses and reactions of all the stakeholders of the DEP and the conclusions arrived at in the process. The effectiveness of the DEP is also analysed in this section.

Analysis and Inferences

The effectiveness of any programme can be determined by analysing the feedback from the various entities involved.

Faculty feedback

Faculty members who have participated in the DEP have been asked to respond to questions like the following:

- Experience of teaching through the DEP
- Quality of participants
- Whether the technology used in the DEP interfered with lectures
- Interaction of RC participants
- Support provided by the DEP team
- Offering a further course through the DEP

The feedback from twenty DEP faculty members is summarised below in Table 1.

Table 1 Faculty feedback

a.	Experience of teaching through the DEP	Excellent – 80% Good – 10% Average – 10%
b.	Quality of participants in the DEP	Good – 50% Average – 30% Below average – 20%
c.	Whether the technology used in the DEP interfered with lectures	Not interrupting – 95% Interrupting – 5%
d.	Interaction of RC participants	Satisfactory – 75% Not satisfactory – 25%
e.	Support provided by the DEP team	Excellent – 90% Good – 10%
f.	Offering a further course through DEP	Yes – 95% No – 5%

An interesting observation made by one faculty member was "…because of the pressure of being captured on camera and being seen by other participants at remote centres, the local students were better prepared for the class and participated in discussions in a more meaningful way. This made my classes more lively and interesting…"

Participant feedback
The participants were asked to respond to questions like:

- Coverage of course materials
- Faculty presentation skills
- Adequacy of interaction with faculty through the remote technology
- Reception of lectures at RCs
- Support provided at RCs
- Recommending DEP courses to others

A sample feedback summary from a recent course involving sixty participants is shown below in Table 2.

Table 2 Participant feedback

a.	Course material satisfactorily covered	Yes – 91% No – 9%
b.	Faculty presentation skills	Good – 93% Average – 7%
c.	Adequacy of interaction with faculty through the remote technology	Yes – 92% No – 8%
d.	Reception of lectures at RCs	Good quality – 95% Average quality –5%
e.	Support provided at RCs.	Good – 85% Needs improvement – 15%
f.	Recommending DEP courses to others	Yes – 97% No – 3%

One of the participants stated "… I was a DEP student for Mobile Computing and want to inform you that because of upgrading my knowledge through this course, I have been offered a new job. I want to convey my thanks to the faculty and the DEP team…"

Remote Centre Feedback
All the coordinators at participating RCs of the DEP meet every semester to give their feedback to the central site and offer suggestions on ways to improve the programme and increase student registration. One of the RC coordinator said, "…we are very proud to be associated with an impressive programme like the DEP which in turn is serving our local participants." One of our corporate RCs said, "...The DEP programme enables us to upgrade the skills of our employees. Through DEP access to the distinguished guest lectures are also proving to be very helpful…"

Service Provider Feedback
The network maintenance and service provider is also very committed as it is eager to be a part of the DEP; this is not only for commercial reasons but because it also addresses the social cause of spreading education to remote areas in the country. Based on the feedback presented above, we found that:

- The faculty members unanimously enjoyed offering courses through the DEP.
- Participants have benefited from the courses.
- The RCs are glad that the remote participants are getting access to IIT lectures.

Hence we believe that as a quality learning environment, the DEP is effective. In the next section, we will discuss some extensions models of the programme.

Economics and Scaling

Being satellite based, the DEP has operational costs, which is more than that incurred by conventional models of distance education. Nevertheless, such a model is economically viable because most of the costs is in setting up the studio at the central site and the satellite bandwidth, both of which are borne by the central site. Setting up of a new RC requires only 10% of the central site investment. The revenue model also apportions a share of the fees to the RC (40% in the case of the DEP), thereby making it attractive for the RCs. The DEP model can be easily scaled by:

- Increasing the number of RCs and thereby the number of remote participants.
- Offering foundation level, undergraduate and postgraduate courses across different disciplines.
- Utilising the bandwidth by also transmitting to the RCs any short-term courses, workshops, seminars and invited distinguished lectures which may be held at the central site.

Also, an added advantage of conducting short-term industry-specific specialised courses over the DEP is that it offers working professionals a chance to enhance their skills without having to travel to a central location.

The Current DEP Status

Over the past seven semesters, the DEP has offered a wide range of courses in the fields of subjects like Embedded Systems, Mobile Computing, Distributed Systems, Communication Networking, Database Management, Digital Signal Processing, Data Structures, etc. Besides the regular semester-long courses, short-term courses and numerous guest lectures by eminent faculty members have also been conducted. Details of the number of students trained through the DEP are given in Table 3. A total of 43 long-term (semester-long) courses and approximately 25 short-term courses and invited lectures were transmitted over the past seven semesters.

Table 3 Number of students trained through the DEP

SEMESTER	Registration	
	Long-term	Short-term
Pilot Programme (March - May 2002)	78	-
Fall (Aug - Dec 2002)	145	-
Spring (Jan - May 2003)	389	-
Fall (July - Dec 2003)	288	260
Spring (Jan - May 2004)	293	1060
Fall (July - Dec 2004)	562	810
Spring (Jan - May 2005)	596	344
Total		4825

Figure 8 depicts the cumulative registrations for long-term courses over the past seven semesters.

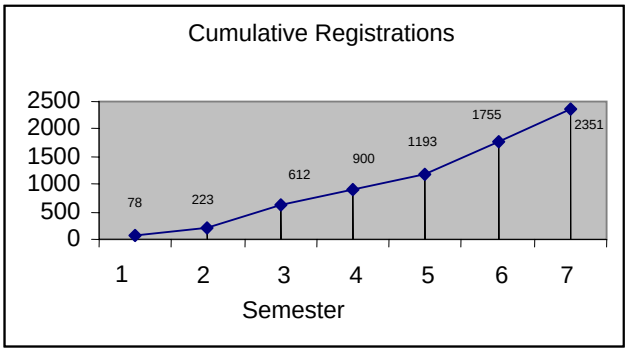

Figure 8 Cumulative graph of registrations

In summary, over the past seven semesters, the DEP has benefited approximately 5,000 participants from RCs across the country.

Conclusion

In this paper we have described the DEP, a satellite-based distance education model with the key features of interactivity, scalability and reusability. Although a satellite-based model does not typically allow transmission across the country borders, with the increase in the use of broadband technology around the world, the streaming model has shown that it has great potential for growth in the near future. The DEP is effective in enhancing the expertise of teachers and providing quality education to students and working professionals from geographically diverse areas. We feel that such a model can be easily replicated in other countries as well.

Acknowledgement

The Distance Education Programme (DEP) was initiated by Prof. D.B. Phatak at IIT Bombay. Prof. Kavi Arya was instrumental in setting up the initial infra- structure. The DEP has been made possible though the ongoing dedicated efforts of a growing team of faculty, programme managers and RC co-ordinators, involved in the various aspects of production and running of the programme.

Prof. M.U. Deshpande is at present heading the DEP team and motivating the members to achieve their goal. We are also privileged to have the continued support of our network service provider and course participants.

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