Use of Technology in providing Quality Engineering Education: Exploring the Indian Experience

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Abstract

Using the functions of innovations systems approach, this paper tries to understand and compare the use of two technologies, namely satellites and internet, in engineering education. This is done by analysing the experience of Indian Institute of Technology (IIT) Bombay distance education network and the National Programme on Technology Enhanced Learning (NPTEL) launched jointly by the Indian Institutes of Technology and the Indian Institute of Science. In the satellite network the initial strong thrust could not be sustained as IIT Bombay network was unable to provide connectivity fast enough for the rapidly growing demand across the country, and had to find an alternative technology to provide distance education. NPTEL provided the alternative technology IIT Bombay distance education network was looking for. Our analysis using the functions of innovations systems approach suggests that NPTEL has fared better than the satellite network of IIT Bombay. The initial strong thrust in NPTEL, which generated a lot of interest, has been sustained; the network has been able to cater to the huge demand for quality content. A natural conclusion from the case studies described in the paper is that a policy intervention that aims to use technology for better delivery of services should keep in focus the capabilities of all the actors involved, as well as strive for organisational arrangements and mechanisms that are based on the opportunities and incentives of these actors.

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1 Background

In today's world, engineering is an intrinsic part of almost every economy in the globe. There are very few sectors in the economy that are not enabled by engineering. A wide range of skill and knowledge is required for successful engineering activity. The backbone of such a successful engineering activity is undoubtedly the nation's system of engineering education. However, in the Indian case, there are a number of issues that have plagued the system of engineering education. The key issue that has impacted the system is the lack of qualified faculty, as it has been seen that in the thousands of engineering colleges that dot the nation inexperienced and undergraduate degree holders are appointed as lecturers, which feeds to the gap between the desired level and the current level of expertise available among the faculty. The tiny elite sector in the system the Indian Institutes of Technology (IIT) at the national level and a group of prestigious institutions at the State level, seem to be less affected by this gap. Rest of the sector, most of which are privately run engineering colleges, has been responsible for the rapid growth in engineering education and hence educate a vast majority of Indian engineers (Walsh 2011). A majority of these fresh engineers who have been trained by this combination of lack of quality faculty and subpar private engineering colleges have already been labelled as 'unemployable' by the major employer, the Indian software industry.

This problem has been recognized by the Government of India and there are steps that are being taken not only by the concerned department but also by the Indian Space Research Organization (ISRO) and the IITs. In September 2004, ISRO launched an educational satellite 'EduSat', built exclusively for serving the educational sector. EduSat was primarily meant for providing connectivity to school, college, and higher levels of education. By establishing connectivity between urban educational institutions imparting quality education and rural and semi-urban educational institutions, EduSat intended to address the deficit in rural educational infrastructure and non-availability of good teachers in sufficient numbers. Institutes like the Indian Institute of Technology (IIT), Bombay, have used the EduSat to enhance their distance education programme. During the same time, the IITs and the Indian Institute of Science (IISc) came together to put forward a proposal to the Government of India's Ministry of Human Resource Development to create content for 100 courses as web-based supplements to be distributed through the Internet. Thus the National Programme on Technology Enhanced Learning (NPTEL) initiative was born, which created complete, free and open online courseware for engineering, science and management subjects. This initiative has been used to train teachers in Indian technical institutions; to help improve the overall quality of technical and professional education, and the employability of Indian graduates. The contents of NPTEL are available free to everyone in the world and follow closely the curriculum design adopted by major technical universities in India. As one would expect, the impact of these efforts of using technology in engineering education have been different. This paper tries to understand the experience of using two different technologies in engineering through an innovation systems framework.

The paper is organised as follows, in the next section we briefly explain EduSat and NPTEL followed by a section on the functions of innovations systems and its method of analysis. Section 4 then analyzes using the functions of innovations systems the EduSat and NPTEL interventions in engineering education. Section 5 concludes the paper.

2 EduSat and NPTEL

2.1 EduSat

EduSat, launched on 20 September 2004, was mainly intended to meet the demand for an interactive satellite-based distance education system for the country. This satellite was specially configured for audio-visual medium, employing digital interactive classroom and multimedia multi-centric system. The satellite had numerous technological possibilities for broadcast as well as return links; for example, broadcast was possible through radio, television, and internet. Similarly, webcam, telephone, talkback channel, and internet medium could be used as return link. These numerous technological possibilities were incorporated to give EduSat an edge in providing connectivity to school, college, and higher levels of education and also to support non-formal education including developmental communication. With respect to EduSat, ISRO spearheaded access to this technology by setting up broadcast and receiving terminals. Figure 1 gives the various possibilities of EduSat.

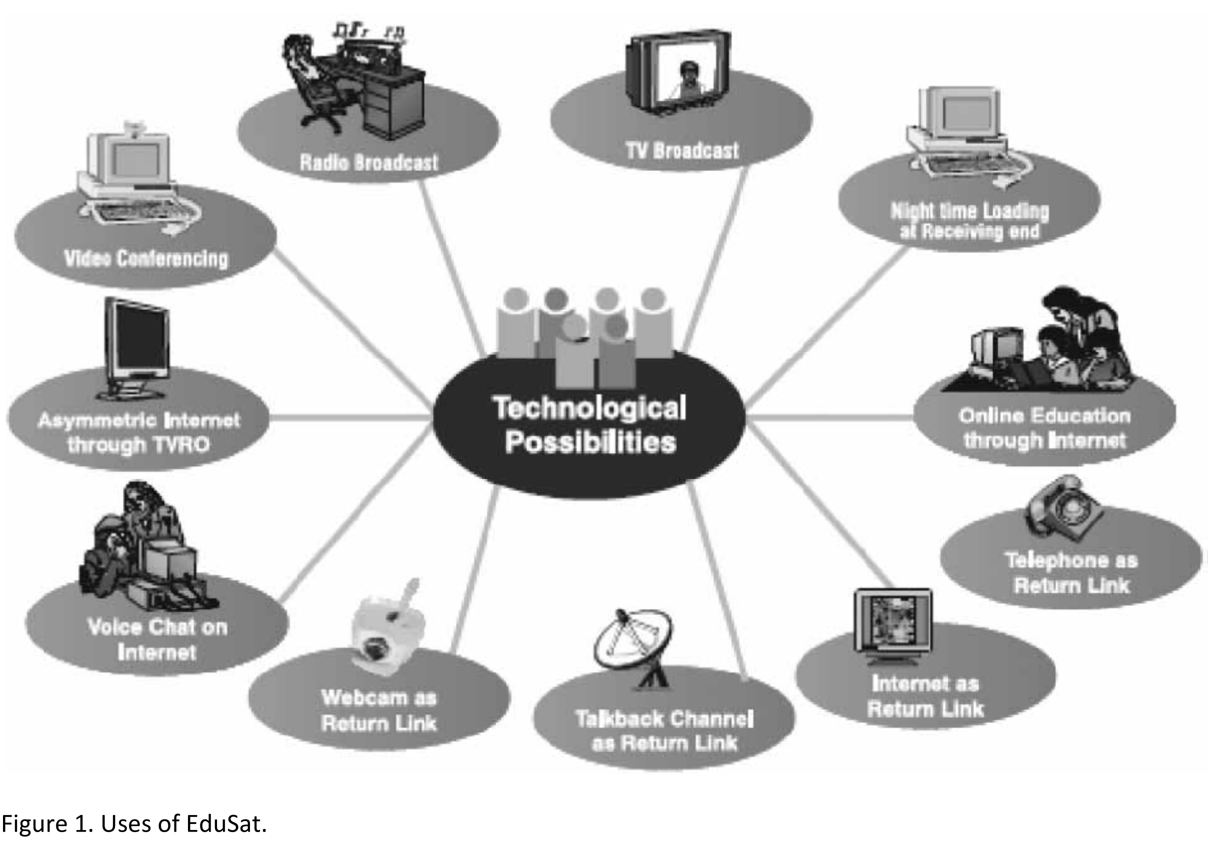


Figure 1. Uses of EduSat.

Source: ISRO brochure on EduSat. Accessed August 22, 2011. http://www.isro.org/publications/pdf/Edusat-Brochure.pdf.

2.1 a Role of ISRO

ISRO conceived the EduSat project in October 2002. Before the launch of EduSat, ISRO initiated discussions and deliberations at a national level to give direction to the 'EduSat Utilization Programme'. A series of consultations, seminars, and workshops were organized with an objective to develop a road map for ground segment, utilization, and preparedness. All the stakeholders who were participants in these seminars were familiarized with the concept, technology, applications and proposed process of implementation, and issues in terms of operations and management of the network and utilization. The topics of the discussions covered levels such as elementary, secondary and higher secondary, higher, technical and vocational, distance, teachers training, and women's education. Discussions were also held on a variety of issues including the subjects that could be taken up for teaching, interactivity, and quality of content etc. ISRO then set up appropriate project-structure to monitor, supervise, and formulate the policies and guidelines to run this programme. ISRO implemented the 'EduSat Utilization Programme' in three phases: pilot, semi-operational, and operational. In the pilot phase, which was before the launch of EduSat, engineering colleges of three universities, one each in Maharashtra, Karnataka, and Madhya Pradesh were connected through three independent networks using Indian National Satellite System (INSAT) 3B Ku-band transponder (Bhaskaranarayana, Varadarajan, and Hegde 2009). To make optimum use of EduSat capabilities, ISRO asked the National Institute of Advanced Studies (NIAS 2005) to review the Visvesvaraya Technological University – EduSat pilot project in 2004–2005 in Karnataka. The main aim of the study was to suggest guidelines that would help fine tuning and utilization of EduSat, by understanding various aspects such as technical, institutional, managerial, and educational content. The study noted that the gap between planning and execution led to a lack of sense of ownership among actual users. This meant a lack of engagement which led to widespread marginalization and subsequently its insufficient usage. The report then went on to make numerous recommendations for improved utilization of EduSat.

Another study Bhatia (2009), on the usage of EduSat, noted that the primary mode of use of the EduSat system was either broadcasting or conduct of live interactive classes. Though each user was required to invest substantially in a hub, use of the offline mode was very little. The absence of offline usage led to the satellite being almost unused during non-office hours, implying that usage for educational purposes between 6.00 pm and 9.00 am was very minimal. Internet connectivity was not made available to users either due to fear of overload or viruses. Centralized databases of teaching/learning materials could have been created for ongoing use, which, due to various reasons did not happen; even existing databases and data banks were not connected. This study also highlighted some technical problems, for example, since some states were not fully covered by any single regional beam, these states had to be provided bandwidth on the national beam. This led to a situation of spare capacity on some regional beams and overloading of the national beam. Connectivity between national and regional beams was not possible. If a state network wanted to use/redistribute the signal of a national beam it was not possible.

2.2 NPTEL

The NPTEL programme began in 2003, with an aim of creating 120 internet based course supplements, 115 video courses and encapsulation/conversion of existing 110 video courses. Each web course that was to be developed would comprise of supplementary learning materials for 40 hours; the 115 video courses were supposed to contain approximately 40 one-hour lectures per course and were prepared in a broadcast format for telecast through 'Eklavya' channel made available by the Ministry of Human Resource Development (MHRD) exclusively for this purpose. Formally launched in September 2006, more than 80 per cent content in NPTEL has been designed and developed for dissemination through the web. The video lectures are being broadcasted through the Eklavya channel, and approximately 50 engineering institutions across the country have set up their own receivers with a dish antenna to receive the signal in their campuses. Thus NPTEL is a curriculum development exercise in electronic form with the specific objective of improving the quality of engineering education in India through distance mode. These courses were initially meant to be used as ‘teacher-education’ material – intended to provide teachers with requisite knowledge in various areas of undergraduate education. Of course, the material could also be used as ‘support/reference material’ for students in different streams of engineering education.

2.2 a Role of IITs and IISc

In phase one of the NPTEL programme, each of the eight partner institutions (comprising of the IITs and IISc) identified individual faculty members to represent their institutions in the group of Technology Enhanced Learning (TEL) Coordinators at the national level, which was responsible for the overall management of content development process in each branch of engineering; at the institute level faculty members in each discipline were also identified as the discipline coordinators to steer the content development programme. The institutes also distributed the work of development of content to the identified subject matter experts in such a way that there was minimum duplication, which also adhered to the common minimum requirements that had evolved for a web / video course. Workshops were also conducted for user faculty from representative colleges in each region; this was for collecting feedback during intermediate stages of content development so that any correction that may be required is carried out. Efforts were also taken to create suitable IT support infrastructure in the form of studios /web content development labs (web studios) and software; it was also ensured that the project staff, which would assist the faculty in content creation, had the requisite training in software skills. Finally, a distribution mechanism for institutions, which did not have dedicated high bandwidth internet connectivity for the web courses, in the form of CDROMs/DVDs was put in place. Two committees were also constituted to coordinate the activities of the national project: the National Programme Committee (NPC), which looked into policy matters and funds allocation to individual institutes, and the Project Implementation Committee (PIC), which delved into all the technical issues associated with the development and implementation process. The second and third phase of the NPTEL programme was from 2007-2012. The major project deliverables here included conversion of NPTEL phase I video courses in streaming video lecture format and setting up eight distributed national video servers for delivering lectures on demand in each of the eight partner institutions. Deliverables also included creation of additional 600 web and video courses in all major branches of engineering, physical sciences at the undergraduate and postgraduate levels and management courses at the postgraduate level.

3 Functions of Innovations systems

3.1 Analytical framework

Success of a new technology with respect to its applications in society is not only determined by its technological characteristics but also by the social system which develops, diffuses, implements or rejects the new technology. The argument in literature is that a 'Technology Specific Innovation System' (TSIS) is a requirement for a technology to be well developed and be fully diffused. TSIS has been defined by Carlsson and Stanckiewicz (1991) as a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilisation of technology. Jacobsson and Bergek (2004) point out that the growth of an emerging TSIS can be stylised by identifying different development phases, such as a formative phase and a diffusion phase. A TSIS consists of three important elements: actors, networks, and institutions. Competence is the key with respect to actors; here it implies technical as well as other types of competence. The importance of `prime movers', i.e. actors who are technically, financially and/or politically powerful that they can initiate or strongly contribute to the development and diffusion of a new technology, has been pointed out by Jacobsson and Johnson (2000). The next important element, networks, constitutes an important mode for the transfer of known and tacit knowledge, and can be conducive to the identification of new problems and the development of new technical solutions (often user-supplier networks). There also exist networks that diffuse more general information. Being strongly integrated in a network increases the resource base of the individual firm (in terms of information, knowledge, technology, etc.) and therefore, its degrees of freedom. Networks also influence the perception of what is possible and desirable, which guide specific investment decisions, which also implies that networks constrain the individual firm in its technology choice. The final important element of a TSIS, institutions, can be `hard' ones, such as legislation, the capital market or the educational system, or softer ones such as culture (Jacobsson and Johnson, 2000). The roles of the different institutions vary; some institutions enable a high connectivity in the system, whereas other institutions influence the incentive structure. This makes it clear that institutions have the ability to affect the specific path a technology takes.

To unlock and displace an existing system, it is important that several TSIS develop successfully and take over part of the existing system. The determining factors for a TSIS can be traced by identifying all those activities that take place in innovation systems that influence the development, diffusion and use of an innovation. These activities are also called 'Functions of Innovation Systems'. Hekkert et al (2007) point out that there are three reasons for adopting the functions of innovation systems approach. First, this perspective makes comparison in terms of performance between innovation systems with different institutional set-ups more feasible. Second, the functions perspective permits a more systematic method of mapping determinants of innovation; this increases the analytical power of the innovations systems approach, especially when doing a longitudinal analysis. Third, the functions perspective has the potential to deliver a clear set of policy targets as well as instruments to meet these targets. The seven functions proposed by Hekkert et al (2007) are as follows

• Entrepreneurial activities (F1): Entrepreneurs are critical to any innovation system. Their role is to generate and take advantage of business opportunities resulting from development of new knowledge, networks, and markets.

• Knowledge development (F2): This activity is at the core of any innovation system and includes research and development, learning by doing, and learning by searching.

• Knowledge diffusion through networks (F3): Exchange of information through networks is an important activity for any innovation system. The flow of information/knowledge can be from research to policy circles and vice versa, and similarly from research to users and vice versa.

• Guidance of the search (F4): This function includes activities in the innovation system that can positively affect the visibility and clarity of specific wants among technology users.

• Market formation (F5): Since a new technology often has difficulties to compete with incumbent technologies, market formation activities are important functions for any innovation system.

• Resources mobilization (F6): Within an innovation system, resources (financial and human) are the basic inputs to all the activities.

- Creation of legitimacy/counteract resistance to change (F7): In order to develop, a new technology has to become part of an incumbent regime, or has to even overthrow it. It is possible that vested interests will often oppose this force of 'creative destruction'. Thus advocacy coalitions can function as a catalyst to create legitimacy for the new technology and to counteract resistance to change.

It must be mentioned that functions influence each other; fulfilment of a certain function quite likely has its effects on the fulfilment of other functions, thus leading to interactions among functions. New developments often start with a limited number of functions that often pull other system functions innovation system gains strength.

3.2 Methodology

Hekkert and Negro (2009) point out that the method used to map interaction patterns between system functions is inspired by the process method called 'Historical Event Analysis'. The goal of an event history analysis (EHA) is to explain a qualitative change (an "event") that occurs in the behaviour of a unit (can be an individual or any collective) at a particular point in time (Berry and Berry, 1990). The event history is a longitudinal record showing whether and when the event was experienced by a sample of units during a period of observation. The event history variable in EHA is a dummy variable that is scored one for each case when a unit experiences the event, zero otherwise. Thus EHA has several advantages for innovation research. First, it is suitable for testing a theory of innovation incorporating all the determinants. It can also assess the effects on the probability of adoption of characteristics of actors/units that vary substantially from year to year, as annual longitudinal variation is incorporated in the data set. Finally, its use to study innovation can dramatically increase the substantive relevance of research findings in the literature. In empirical studies on system functions this analysis is applied at the TSIS level. This approach consists of retrieving as many events as possible that have taken place in the innovation system using archive data, such as newspapers, magazines, and reports. The archive is complemented with articles from professional journals. The events are stored in a database and classified into event categories. Using the classification scheme noted in Hekkert and Negro (2009), each event category is allocated to a system function. The contribution of an event to the fulfilment of a system function may differ considerably from event to event. Some events have a positive contribution to the diffusion of the technology, while others may contribute negatively. This is indicated in the allocation scheme by a positive sign and negative sign, respectively. The balance between positive and negative events yields specific insights into the slowing down of system growth or into controversies emerging around the analysed technology. Since the importance of an event is not known beforehand, it is not weighted in this methodology.

The functions of innovations systems framework has been generally used in the energy domain, mostly in the European context. In the Indian context, Iyer (2014) uses this approach to understand the use of satellites for access to education. The paper analyzes the experience of IIT Bombay distance education network and the primary school network in the Hindi speaking states of India. In both of these networks the analysis shows that the initial strong thrust could not be sustained. Though lack of resources was the main reason in the both the networks, the pre cursor for the lack of resources was different for each of the networks. IIT Bombay network was unable to provide connectivity fast enough for the rapidly growing demand across the country and had to find an alternative technology. With respect to primary school network, the key resource crunch was with respect to trained manpower and security personnel for the equipments deployed, and lack of support from softer institutions like culture.

We now explain the analysis of the IIT Bombay distance education network from Iyer (2014) and then analyse the NPTEL programme. We then compare these two analyses to bring out some useful implications.

4 Case studies on use of technology in engineering education

4.1 Case study 1: Indian Institute of Technology, Bombay EduSat network

The Indian Institute of Technology, Bombay has used the services of EduSat to enhance its distance education programme. Moudgalya et al (2009) state that IIT Bombay ventured into distance education with an aim to reduce the paucity of good teachers across engineering colleges in India, as well as allow satellite transmission of its courses as a part of its social responsibility. Before using EduSat, IIT Bombay tried a commercial model where bandwidth was bought and access was given at a cost to students at remote centres. At the start of the satellite transmission, IIT Bombay had expected that the distance education programme would grow rapidly. However, this did not happen due to two reasons, since advanced courses were transmitted during this period, distance education students found the courses to be of high level; and second, reluctance of IIT Bombay to certify more than a limited number of external students. The private company HCL Comnet that provided this service found it difficult to maintain the equipment because of low volumes (number of remote centres for satellite transmission remained at about 15). Because of poor maintenance, infrastructure started crumbling resulting in poor quality transmission and lesser enrolment, which raised a question on the viability of the programme.

Around the same time, ISRO was looking for content for EduSat, which opened the possibility of IIT Bombay collaborating with ISRO. However, ISRO had two conditions, one on free transmission and the other on no encryption, which made IIT Bombay initially reluctant. This was because, IIT Bombay had no support to cover the expenses of its distance education programme, and unencrypted transmission of lectures could result in misuse by some private colleges. ISRO and IIT Bombay addressed these two concerns by allowing the basic transmission to be free; and allowing for charges in cases where additional recognition was desired, such as, certification, etc. ISRO, in return for a guaranteed number of free courses during day time, also offered to lock out the general public from accessing courses beamed in the evenings for corporate participants. Although a memorandum of understanding containing these terms was agreed to, IIT Bombay transmitted all the courses through EduSat free of cost.

When IIT Bombay switched over to EduSat, there were about 40 remote centres that could receive their transmission - all of them had been given the equipment free of cost by ISRO. As per the paper Moudgalya et al (2009), including those in the pipeline there were about 90 remote centres. The new remote centres paid a onetime charge of about Rs. 500,000 to establish the infrastructure. The growing numbers, as per Moudgalya et al (2009) indicated the popularity of the IIT Bombay EduSat programme. This paper also points out that transmission through EduSat was preferable as it offered a guaranteed bandwidth at no cost for IIT Bombay and for each of the remote centres in the network, which was in addition to its reliability. When IIT Bombay signed up with ISRO, different national dailies covered the event and students from all over the country wrote mails enquiring when a remote centre would be established in their town. However, ISRO generated invoices only after a minimum number of applications were received as a result it used to take anywhere between two to six months to establish an EduSat receiving station at a remote centre. Moudgalya et al (2009) also note that while utilising EduSat, IIT Bombay was hampered by the lack of two essential infrastructure facilities. First, it did not have a receiving station. Second, the hub was located at Amrita University in South India and not at IIT Bombay, which resulted in additional coordination difficulties. Ensuring that every remote centre was in working condition also required a lot of work and coordination with the service provider (in this case, Bharat Electronics Limited); as a result many remote centres went inactive. As per the presentation Moudgalya (T4E, 2009), out of the 65 remote centres only 25 were active in 2009.

The growing demand for its courses across the country made IIT Bombay realize that it had to cater to the demand at a reasonable speed. However, given the challenges faced with respect to the time required to establish a remote centre, the coordination effort to keep it active, and the fact that IIT Bombay had only one channel on EduSat and was already fully using it; IIT Bombay concluded that it could not handle the demand for its courses across India using only EduSat. This compelled IIT Bombay to explore the possibility of using other technologies including live webcast. Moudgalya et al (2009) also point out that if lectures are recorded and immediately put on a content distribution network, a lot more students are benefited by webcast.

4.1a Functioning of system

Let us now try to understand the IIT Bombay EduSat network through the lens of the functions of innovations systems. Here we essentially map the various activities in the system to the closest functions. The main guiding factor (F4) for IIT Bombay and ISRO to initiate satellite transmission for distance education was responsibility towards society. This inspired both of these institutions to start their entrepreneurial activities (F1), collaborate with each other (F1) and use their resources (F6) towards the objective. The coverage by the media increased visibility and demand, resulting in the increase of the market size (F5). For the generated positive momentum to be sustained and the TSIS to be successful, one can identify at least three necessary conditions which needed to be fulfilled. First, the infrastructure should be rolled out before the enthusiasm for the technology reduces. Second, there should be as little as co-ordination problems among the various actors of this TSIS, this is for both the phases i.e. the set up of infrastructure phase as well as the during the actual transmission phase. Finally, a better technology does not arrive at scene to challenge or substitute this technology. Given the nature of users (primarily engineering students completing a four year course and engineers looking for additional certification) it was imperative that the first two necessary conditions be met as soon as possible as users were more likely to embrace a more friendly technology, just in case if it were to arrive and challenge this technology. The intensity of the actual events in this system led to increase in the IIT Bombay EduSat network size and intensity over time (F5), though not to the level of the demand that was generated. This is because, it is clear from the facts stated above that there was a mismatch between the demand generated and the capability of the network to expand. To put in the functions of innovations systems perspective, the system lacked the resources (-F6) to cope up to a huge spurt in demand in such a short time, as well as to address the coordination problems that arose in the IIT Bombay EduSat network (-F6). A new technology i.e. webcast also entered the scene, webcast could cater to the spurt in demand with lesser resources, and more flexibility with respect to the user; thus webcast challenged the EduSat technology (-F7). The advantage of webcast was that the lecture could be hosted at a website, which could be later accessed by a student as per her/his convenience. As a result, in order to reach out to more towns in the country, IIT Bombay started using live webcast in addition to using EduSat for the established remote centres. The impact of these developments on the positive momentum of the system can be understood from the fact that out of the 65 remote centres in the network only 25 were active in 2009 (i.e. around 38 per cent) reducing the growth as well as impact of the TSIS. This clearly shows that with respect to the IIT Bombay EduSat network, the initial positive momentum was countered by the negative momentum that was generated due to the various inadequacies in the system.

4.2 Case study 2: NPTEL

NPTEL was formally launched in September 2006 with more than 80 per cent content in being designed and developed for dissemination through the web. As per Walsh (2011) the most striking feature of NPTEL is its consortial structure, as the eight partner institutions compete with each other for faculty and students. Moreover, this is as per him the IITs deepest and most high-profile collaboration to date, as it required all partner institutions to build consensus on fundamental curricular issues. NPTEL‘s organizational leadership is drawn entirely from the faculty and administrative ranks of its partner institutions and lacks a central, physical space. Walsh (2011) notes that the scope of the NPTEL effort is significant as almost 350 faculty were involved in creating content for NPTEL; and coordinating this faculty effort itself has been a successful experiment in cooperation. This has resulted in a great deal of content, between the site‘s launch in 2006 and the completion of Phase I in the summer of 2007, NPTEL produced 239 courses, 110 of which had 40 hours of video lectures. Walsh (2011) mentions that the NPTEL team's only marketing were probably the mailings on NPTEL that were sent to about 2,200 Indian colleges on two different occasions. Though the awareness of the initiative is not as widespread as the NPTEL team might like, the site has attracted its users with minimal outreach and very little marketing. When the website was launched, free registration was required, but the practice of registering users and requiring passwords was ended in November 2007 to encourage greater usage. He also notes that NPTEL received over 100,000 visitors per month in the fall of 2008, with video courses being more popular than the web courses. This is despite the fact that the initiative was not interested in drawing attention to itself in Phase I, though all involved in the effort realized that more outreach would be necessary in the future to increase awareness of the project.

In contrast, Ravi and Jani (2011) point out that promotion of NPTEL has been done using many different methods. Posters and brochures have been sent by post to more than 3,500 institutes across the country. Emails and bulk short messaging services (sms) have been sent to the available data of all principals and placement officers of various colleges across the country. Team from BodhBridge (a company incubated in IIT Madras) has visited nearly 350 engineering colleges across the country (Maharashtra, West Bengal, Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, etc.). This has been supplemented with online competitions and the selection of student ambassadors across different campuses. They also note that for the period ending March 2010, students (47 per cent of total users) and faculty (10 per cent of total users) from 93 universities across the country and working professionals (43 per cent of total users) from 175 public and private sector companies were using NPTEL. The study also generated a total of 906 survey responses from eight engineering colleges in Gujarat; among the 875 that were considered for final analysis 287 (32.8 per cent of 875) had used NPTEL. Of the 287, 61 (21.2 per cent) were faculty members and 226 (78.8 per cent) were students.

Another study by Sarvanan and Esmail (2014) looks at the availability and impact of NPTEL in seven selected engineering colleges (among 33) in Thiruvallur district, Tamil Nadu. This study which analysed 300 survey questionnaires received from these seven colleges, found that 223 respondents accessed NPTEL through the library, 32 accessed NPTEL from computer lab and college hostel, 28 respondents accessed NPTEL through browsing centres, and the remaining 17 respondents accessed NPTEL from their home. This clearly hints that access to NPTEL for engineering students and faculty has to be shared, which clearly will limit the time an individual can spend benefitting from NPTEL.

To understand the reach of NPTEL let us look at some statistics. It must be mentioned that, as per NPTEL website, as of 14th July 2015, officially there were 982 engineering institutions across the country that were using NPTEL. Table 1 shows YouTube statistics at different time points. It can be seen that as the number of courses and video hours have increased, the channel views and subscribers have increased at a faster rate. This clearly shows that more and more engineering students, professionals, and faculty started accessing NPTEL by April 2012.

Table 1: NPTEL-YouTube statistics

As on	Videos	Number of courses	Channel Views	Subscribers
Nov 01, 2008	3198	83	192,224	6,536
Sep 15, 2009	3965	112	1,416,203	23,743
Apr 19, 2010	4407	123	2,671,757	38,529
Aug 12, 2010	4618	129	3,227,970	46,385
Apr 16, 2012	6466	172	21,961,826	97,749

Source: Presentation 'NPTEL – Phase II, Meeting of SMEs @ IITM', 17th April 2012.

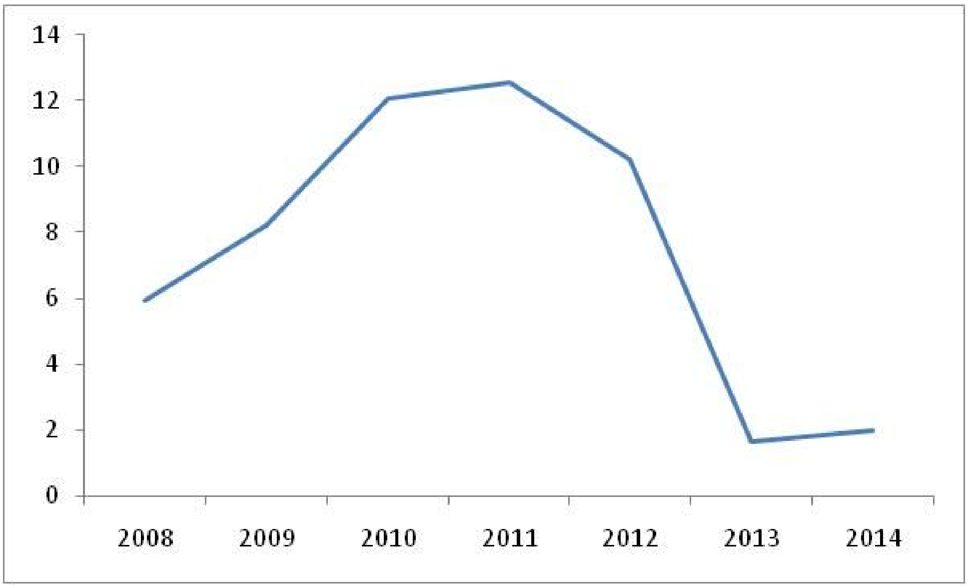
Table 2: NPTEL-YouTube statistics

Period	Videos	Channel Views
Jan-Dec, 2008	3198	6,939,361
Jan-Dec, 2009	3965	11,898,397
Jan-Dec, 2010	4618	20,273,740
Jan-Dec, 2011	6400	29,291,453
Jan-Dec, 2012	10,563	39,482,461
Jan-Dec, 2013	90,480	53,541,773
Jan-June, 2014	92,356	33,177,780

Source: Presentation 'NME–ICT', by Pradeep Kaul, at "One Agriculture-One Science", Telangana, 9th March 2015.

Table 2 shows the video hours and the channel views for comparable periods of time; we assume that video hours are cumulative over the years while channel views are the views for that particular period. It is interesting to note that from 2008 to 2013 while video hours has increased by a factor of almost 30, the channel views at the maximum has increased by a factor of nine. The probable reason for this could be that the added new video courses would have been for streams that have lesser intake of students across the country, which shows up as a lesser increase in channel views. If one analyses the numbers in table 2 by channel view per video hour per day, then it shows us a pattern which is rather interesting, this can be seen from chart 1.

Chart 1: Trend of views per video per day



Data source: Data presented in table 2

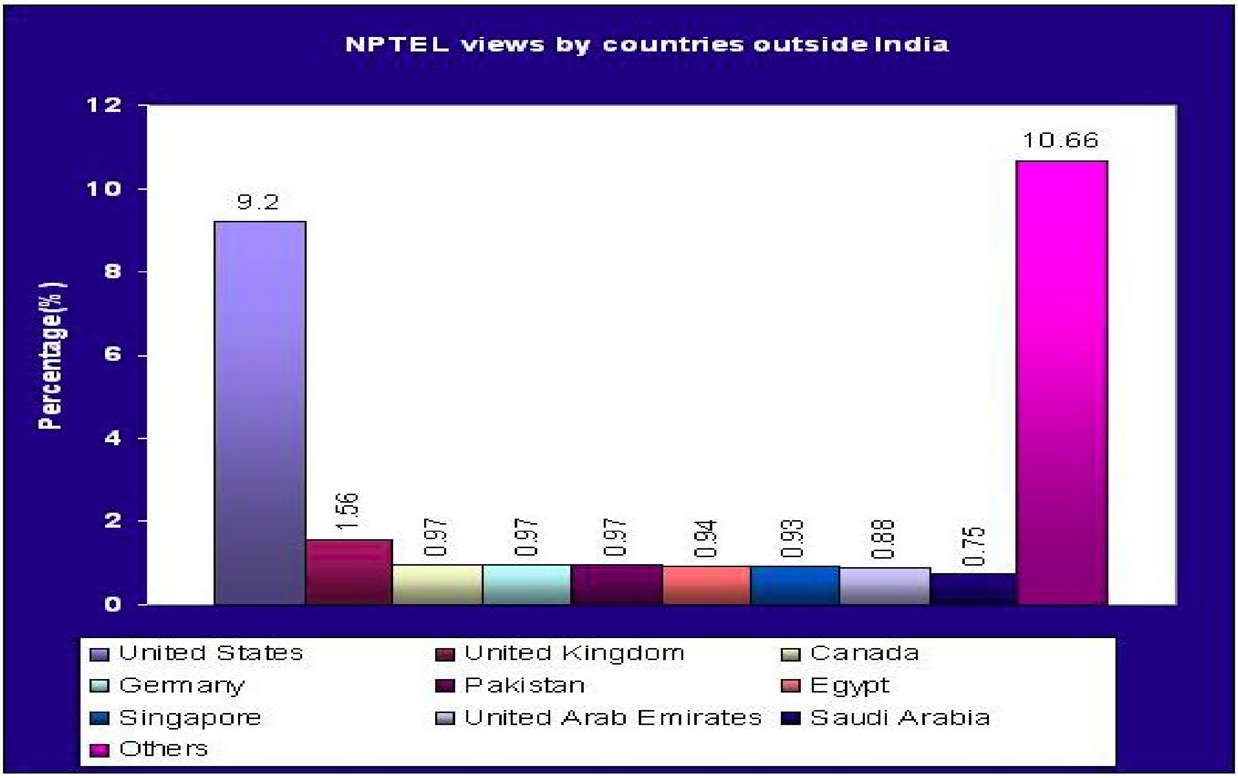
The trend was of increase from 2008 till 2011, with a slight decline in 2012 when the video hours increased from 6,400 to 10, 563. There is drastic drop in the year 2013 when the video hours increased from 10,563 to 90, 480. As can be seen from the chart, the trend has shown an increase in the first half of 2014. It could also be possible that users are now accessing this content through other means, for example, through the Ekalavya channel which also beams these lectures, or users may have downloaded the lectures which may have brought down the view per video per day. Thus there is a need to study this particular aspect in detail, which is not within the scope of this paper. It must also be mentioned that the time spent[2] by each user on NPTEL-You Tube or on the videos is an important parameter, to better understand the reach of NPTEL. Since, we do not have those numbers at this point of time we are unable to comment on them.

What emerges out of this whole exercise is probably the fact that compared to earlier attempts NPTEL has been able to reach out to larger audience. Chart 2 testifies this

[2] I thank the referee for pointing this out.

statement. 27.83 per cent of the users of NPTEL are not from India. It has users from the United States, United Kingdom, Canada, Germany, Pakistan, Egypt, Singapore, United Arab Emirates, Saudi Arabia, and other countries. It is quite possible that the Indian Diaspora in these countries may be accessing NPTEL; this reason in no way reduces the accomplishment of NPTEL.

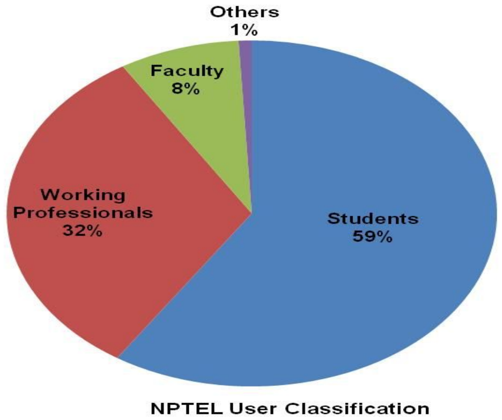
Chart 2: NPTEL user profile outside India



Source: Presentation 'NME–ICT', by Pradeep Kaul, at "One Agriculture-One Science", Telangana, 9th March 2015.

A preliminary net survey with about 5000 NPTEL users in the few months before September 2012 showed the following results.

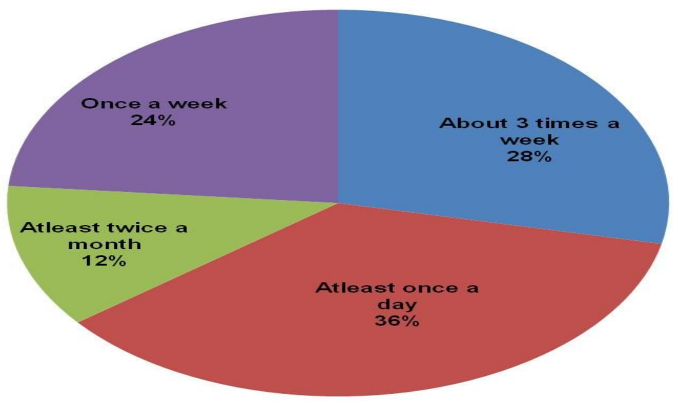
Chart 3: NPTEL User Classification



Source: Presentation ' Technology-Enabled and Technology- Enhanced Open Educational Resources', by Mangala Sunder Krishnan, at OER Symposium, September 2012, Penang, Malaysia.

Chart 3 shows the NPTEL user classification, it can be seen that at 59 per cent a majority of the users are students while almost a third of the users are working professionals. Faculty users of NPTEL are relatively lesser at eight per cent, this seems to be in consonance with anecdotes[3] from field that faculty in other universities and colleges did not like using NPTEL in their regular courses as it showed them in a bad light. Chart 4 shows the frequency at which users refer to NPTEL, just over a third of the users access NPTEL on a daily basis; the percent of users who access NPTEL on a daily basis is equal to the per cent of users who access NPTEL a maximum of four times a month.

Chart 4: Frequency of referring to NPTEL



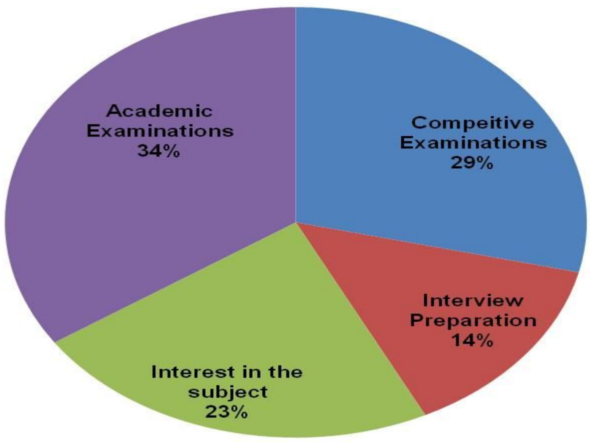
Source: Presentation ' Technology-Enabled and Technology- Enhanced Open Educational Resources', by Mangala Sunder Krishnan, at OER Symposium, September 2012, Penang, Malaysia.

About 28 per cent of the users access NPTEL 3 times a week. Given the high student intake of engineering students across various colleges in the country, this probably shows the lack

[3] 'NPTEL: A Bold Initiative to Enhance the Quality of Indian Engineering Education', by Rishikesha Krishnan, Accessed from http://jugaadtoinnovation.blogspot.in, as on 14/May/2015.

of facilities to access NPTEL. Chart 5 shows the purpose of using NPTEL, it can be seen that just over a third of the users access NPTEL for academic exams, while around 29 per cent access NPTEL for competitive exams. 23 per cent of the users use NPTEL for their interest in the subject while 14 per cent use NPTEL to prepare for interview. The almost one to one mapping in percentages between chart 4 and chart 5 may have some underlying reason, which is beyond the scope of this paper. However, if one looks at these charts with the aim of NPTEL in mind (as a curriculum development exercise), one probably will have to admit that NPTEL seems to have done well. The press coverage of this initiative also been extremely positive and has added to the success of this attempt.

Chart 5: Purpose of using NPTEL content



Source: Presentation ' Technology-Enabled and Technology- Enhanced Open Educational Resources', by Mangala Sunder Krishnan, at OER Symposium, September 2012, Penang, Malaysia.

Table 3 presents a snapshot of the press coverage NPTEL has been accorded. This is not a comprehensive summary but an indicative one. A longer list is available at the NPTEL website.

Table 3: Snapshot of Press coverage for NPTEL

Date	Article	Paper
Nov 27, 2007	NPTEL set for second phase	The Hindu
Dec 08 2007	Thanks, but we don't need your courses: IITs tell MIT	The Indian Express
July 28, 2008	IIT online learning courses gaining momentum	The Hindu
Mar 09, 2009	NPTEL - streaming knowledge to all	The Hindu
May 29, 2011	OpenStudy to forge partnership with NPTEL	The Hindu
Nov 01, 2012	Studying at IITs just a click away, online courses soon	Hindustan Times
Sep 21, 2013	IITs, IISc to take engineering to rural areas	Deccan Chronicle

Dec 17, 2014	NPTEL announces 11 new online courses	The Tribune
Mar 19, 2015	How NPTEL democratising education and going into the next level	The Economic Times
May 17, 2015	NPTEL – waiting to become a hit among students	The Hindu

The press coverage has also helped students and users to start using NPTEL. Most of the articles listed above are of positive stories about online learning & NPTEL, and probably would have helped the cause of NPTEL in generating further interest.

The success to their efforts has led NPTEL to revisit, what Walsh (2011) mentions that to date, NPTEL's leadership has not considered offering credit or certification to users due to concerns about maintaining the academic standards of the IITs'. However, in March 2014, an online course was started by IIT Madras through NPTEL, after which, 1150 certificates were awarded to candidates who successfully completed the first massive online certification course (MOOC) on 'Programming, Data Structures and Algorithms'. Proctored exams were held at 10 cities across the country to test those who had enrolled for the exams as part of the online course. From the industry, National Association of Software and Service Companies (NASSCOM) collaborated with NPTEL for this effort. As one of the press coverage in table 3 mentions, after the success of the first MOOC, NPTEL has introduced 11 new online courses (NOC). As explained in the press note, NOC ensures student involvement and continued participation during the running of the online course. This is followed by a proctored certification exam with e-verifiable scores that attests the learning of the student and adds value to the resume. Physical certificates will be awarded whose digital versions along with the student scores which can be verified online by prospective employers. The enrolment for these courses is free. The number of cities where exams would be held has been increased from 10 to 100 and the reach has been extended across the country.

4.2a Functioning of system

We now try to understand the important events of NPTEL mentioned above through the functions of innovations systems framework. The goal of NPTEL was to make content available to the largest number of students and engineering aspirants in the country. This was the guidance factor (F4) to unleash their entrepreneurial energy (F1). These functions were responsible for the initial positive momentum of the project. The prior experience of one the partner institutions (F2 and F3) also helped NPTEL to choose webcast as the technology to reach out a wider audience. The growth and use of internet in the past decade has increased exponentially, which had its own positive momentum going for itself. Thus, the choice of webcast by NPTEL to launch their content added to the positive momentum of the initiative (F5). The Central Government (F6) contributed with the financial resources while the partner institutions pooled in the human resources (F6) required for such a huge venture. The amount of coordination and cooperation among the partner institutions (F6) in pursuit of a single goal must also be mentioned here for it kept the positive momentum going. In phase one of the project, though there was some effort towards marketing of the project (F5), the focus was primarily on content creation. In phase two, with increased funding from the Central Government (F6), the efforts of the NPTEL team towards industry-interfaces and certification courses (F6), as well as the increased press coverage resulted in increased views and subscribers not only in India but across the world (F5). The fact that the target group of faculty, working professionals, and students accessed the content implies that NPTEL was able to reach out to its core audience. The tremendous response to the online certification courses, which among others is due to the brand name of the partner institutions as well as the choice of certification courses (F4) that were offered, also stands testimony to the impact of NPTEL as well as the positive momentum gained by the effort. It is clear from the above discussion that many of the functions in this innovation system have been reinforcing each other increasing the impact of the innovation system.

There are few challenges that are not allowing NPTEL to realise its true potential, for example, in one of the studies above it can be seen that most of the students access NPTEL only through the library with very few accessing from their home. This is also reflected in some sense in the drastic drop of views per video per day for the years 2013 and 2014. These may not affect the positive momentum of the current TSIS as these are users who given an option would like to access the content on NPTEL. Though there is transmission through television, as a technology, webcast is more flexible for a user than television. Thus at the end user level there need to be efforts to improve access to the webcast.

5 Concluding remarks

In this paper we used the functions of innovation systems framework to understand and compare the use of two technologies, namely satellites and internet, in engineering education. In the satellite network the initial strong thrust could not be sustained as IIT Bombay network was unable to provide connectivity fast enough for the rapidly growing demand across the country, and had to find an alternative technology to provide distance education. As our analysis above showed NPTEL has fared better than the satellite network, the positive momentum of the initiative has sustained and it has been able to reach a wider audience.

The performance of NPTEL points out to the fact that NPTEL has been able to manage better the process of technological change. Dosi (1997) points out that with respect to understanding technological change it is useful to distinguish between four (albeit interrelated) objects of analysis, namely, first, the changes in innovative opportunities(strictly speaking, the 'sources' of technical change pertain to this domain). Satellite and internet provided an opportunity for the above two networks (EduSat and NPTEL) to induce technological change in the context of engineering education. Second object of analysis is the incentives to exploit the innovative opportunities. The incentive for both the networks was improving the quality of engineering education in the country. Third object of analysis is the capabilities of the agents to achieve whatever they try to do, conditional on their perceptions of both opportunities and incentives. We have already seen that in NPTEL, the partner institutions after coordination, recorded and loaded the content on an established content distribution platform (internet or YouTube), which better suited their capability than the work in EduSat network, which included recording the content as well as coordinating with two other organizations for the content to be beamed. The final object of analysis is the organisational arrangements and mechanisms through which technological advance is implemented. For the EduSat network we have noted that IIT Bombay preferred transmission through EduSat as it offered a guaranteed bandwidth at no cost for IIT Bombay and for each of the remote centres in the network, which was in addition to its reliability. However, for the growth of the network, ISRO generated invoices only after a minimum number of applications were received as a result it used to take anywhere between two to six months to establish an EduSat receiving station at a remote centre. The growing demand for its courses across the country made IIT Bombay realize that it had to cater to the demand at a reasonable speed. However, given the challenges faced with respect to the time required to establish a remote centre, the coordination effort to keep it active, and the fact that IIT Bombay had only one channel on EduSat and was already fully using it; IIT Bombay concluded that it could not handle the demand for its courses across India using only EduSat. In the case of NPTEL, the large scale diffusion of internet as a content distribution platform helped the network to reach a large number of users, who could access the recorded lectures at their convenience. Thus the organizational arrangement and mechanism of NPTEL, with respect to reaching out to a larger audience as well as providing for user preferences and incentives, was better than that of IIT Bombay EduSat network.

A natural conclusion from the above discussion is that a policy intervention that aims to use technology for better delivery of services should keep in focus the capabilities of all the actors involved, as well as strive for organisational arrangements and mechanisms that are based on the opportunities and incentives of these actors. This will increase the chances of a larger and fruitful impact of the policy intervention.

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