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Critical evaluation of existing audio learning systems using a proposed TOL model

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ABSTRACT

This work forms part of a larger research work which advocates that audio-only learning mode can be developed into a full fledge audio-MOOC. The audio-MOOC should incorporate a learner-centric approach to provide effective learning capabilities to the oral and low-literate population. For long, audio-based learning (which includes variances in audio technologies) has been an established practice and has proved to be a successful means of conveying information to the mass especially for illiterate and semi-literate population. However, it is widely used as a supplement to Distance Education mode without exploiting its full potential. This paper aims at providing a comprehensive evaluation of existing audio learning systems which is missing in recent literature. There is no formal and established evaluation framework for evaluating such systems. Hence, this paper contributes to the audio-based learning research area by proposing a Technology, Organisation and Learner (TOL) evaluation model to analyse the existing audio learning systems. The proposed evaluation model uses a set of 50 criteria which is derived from a review of methodologies and strategies for multimedia evaluation. Besides, this work makes use of empirical data in the proposed TOL evaluation model to critically appraise various audio technologies used in learning. Recommendations are made for the development of full-fledge Audio-only Learning Management Systems/MOOCs. Moreover, the proposed evaluation model can also be used for the selection of media suited to the learning needs of organisations.

1. Introduction

Education is a fundamental human right and a powerful tool which can uplift economically and socially marginalized people out of poverty, hence allowing them to engage and contribute fully to the development of their country. This has been recognized by the Universal Declaration of Human Rights (UDHR, 1948) and reaffirmed by the 1960 UNESCO convention against discrimination in education, Education for All (EFA) and member states from United Nations (Craissati, Devi Banerjee, King, Lansdown, & Smith, 2007). UDHR advocates the right of every person to enjoy access to education of good quality, without discrimination or exclusion. Distance Education (DE), for long, has been the enabler of this fundamental right by democratising access to education especially in the developing world and overcoming inherent barriers such as distance, cost, language and culture (Galusha, 1998). Several DE modes, from correspondence courses to Massive Open Online Courses (MOOCs) have emerged allowing large numbers of students to learn at a flexible pace (Aoki, 2012).

Yet, the inability to read and write by illiterate/semi-literate population makes education and hence knowledge transfer a major

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challenge, since most distance education (DE) system[1] devised including the latest MOOCs are based on textual and multimedia content dissemination. Low-literate people are usually from oral cultures and their cognitive representation of ICT interaction are different from literate users (Ong, 1982). Ong's psychodynamics of oral thought advocates an understanding of the fundamental differences between oral and literate users as individuals within the cultural context. The use of spoken language interface has been argued to be the most logical, acceptable and natural way to interact with low literacy population (Agarwal, Jain, Kumar, Nanavati, & Rajput, 2010, Agarwal, Kumar, Nanavati, & Rajput, 2010; Chaudry, Connelly, Siek, & Welch, 2012; Huenerfauth, 2002; Rosenfeld, Sherwani, Ali, & Rosé, 2009). It is intuitive and meaningful to all users irrespective of literacy levels and cultural background (Edim, Muyingi, & Sibanda, 2013). Hence, to digitally include the illiterate/semi-literate population segment in the education system, the use of oral communication and interaction is a requirement.

Audio based learning has been an established practice for decades and has proved to be a successful means of conveying information to the mass (Burns, 2011). Over the years several types of audio technologies have emerged in view of providing the education needs in deprived regions. To overcome barriers of print literacy several authors (Olson, 2006; Ong, 1982; Reimer, 2008) have proposed the use of oral instructions in the learners' native language. Audio technologies compared to recent smarter ones, based on the internet infrastructure, present several advantages since they are considered to be accessible, simple and cost effective particularly in areas of conflict, areas marked by difficult terrain, remote and isolated locations. Besides, they allow doing other activities at the same time of listening.

However, despite the proven success of audio technologies in contributing to knowledge sharing to the mass, they can be criticized for being mostly technology-centered and are used as a supplement to the DE framework, without providing a more holistic approach to audio-only DE. Literature (Mayer, 2002; Sweller, 1994) have focused mainly on multimedia instructional designs which led to the development of several internet-based platforms such as Learning Management Systems (LMS) and Massive Open Online Courses (MOOCs). It is unfortunate that a very thin literature exists for the audio instructional design and even less for a DE audio learning platforms having MOOC features. Challenges such as lack of interactivity, ownership of learning process, feedback, and proper assessment, which are essential to effective learning, are major issues for the audio learning medium. This work is part of our broader objective of implementing a highly scalable Audio MOOC framework over the existing telephony infrastructure. Hence, this work critically analyses the existing audio learning systems in view of identifying the research gaps and shortcomings in making them a full fledge Audio MOOC platform.

1.1. Rationale of the study

Today, nearly 17% of the world's adult population is still illiterate, with some 775 million adults lacking minimum literacy skills. An estimated 122 million youth and 67.4 million children globally are illiterate as a result of deficient or non-existent basic education despite the advent of mobile MOOCs. Besides, even for those attending school, the quality of education is being questioned. Astonishingly, literacy is below 50% in sub-Saharan Africa and in South and West Asia (UNESCO, 2014b). The advent of online learning and MOOCs were supposed to bridge the gap but unfortunately, they failed since they expect a minimum textual literacy from their users. To bridge the digital divide, MOOCs need to be reinvented to recognize the inherent barriers, like connectivity and illiteracy, preventing the have-nots to education and harness its full potential. The striking number of left-outs from the conventional education system in this digital age, the lack of comprehensive appraisal of audio learning systems and a formal evaluation framework makes this study of utmost importance.

This study critically assesses the different existing audio learning systems to develop a more holistic Audio MOOC framework accessed by telephones. UNESCO (2014a) remarked that the world is *book poor but mobile device rich*. Decreasing cost of mobile communications has fueled the proliferation of mobile phones, increasing mobile ownership even at the bottom of the income pyramid. Mobile phone today is considered to be a powerful information carrier which is genuinely and democratically distributed across the world (Velghe, 2012). Statistics clearly demonstrates mobile coverage even in the most deprived region as compared to internet broadband. Though illiterate, most people can make phone calls. By leveraging the existing telephony infrastructure, deprived populations can easily access audio contents by mere phone calls, hence allowing their digital inclusion to knowledge repositories. Audio MOOCs can be used to empower them through education whether informal, formal and lifelong learning practices with all the advantages of mobile learning and MOOCs without any drastic change in their way to communicate, interact and cultural practice.

1.2. Aims and objectives

The main objectives of this research are therefore as follows:

(i) Propose a comprehensive Technological, Organizational and Learning (TOL) evaluation framework for audio learning systems.
(ii) Conduct an in-depth study of identified existing audio technologies used in distance learning systems.
(iii) Critically assess the existing audio learning systems by performing a detailed evaluation using several criteria laid out in the proposed TOL evaluation framework.
(iv) Identify research gaps in the development of an Audio MOOC framework and provide proper recommendations.

[1] System in the context of this paper refers to any combination of components in education technology that allows the delivery of learning contents.

2. An overview of traditional audio learning system

Over decades, several types of audio learning methods have emerged in view of providing education in deprived regions. These methods are based on several available audio medium namely radios, audio-cassettes, CD/DVD and portable media (MP3 Players) players and mobile phones which are very easy to use and widely available technologies all across the globe even in the poorest region. Barron (1999) outlined the advantages of Audio Technology as being an inexpensive technology, easily accessible and easy to use. Only audio can reproduce authentic aural stimuli, the two most common being spoken words and music. Certain characteristics of the spoken word such as intonation and inflection cannot be communicated by other medium (Power, 1990). It brings to the learner the sounds of people and places; the sounds of real and imagined situations; sounds designed to stimulate, support, illustrate and enrich the learning process (Thomas, 2001). For the purpose of this research, the types of audio based distance education have been categorized as follows: Broadcast Radio (BR), Interactive Radio Instruction (IRI), Interactive Audio Instruction (IAI), Audio Conferencing (AC), Call Centre (CC) model and Forum/Knowledge (KN) based. Each type of audio based distance education identified is described below.

2.1. Broadcast radio

Broadcast Radio has been a mass communication tool par excellence for Governments, NGOs and Commercial bodies for sharing knowledge and elementary education to low literacy group. It has been found to be very appropriate in deprived educational system settings whereby radio is already a common technology, there is a scarcity of qualified teachers and where instructional materials have to be disseminated on a large scale such as in India with over 20 million learners (Ho & Thukral, 2009). Radio has been very useful in educating the poor, least supported, remote learners and fragile nations for whom access to education has traditionally been denied (Bakshi & Jha, 2013). Educational radio has addressed a wide range of subject areas, whether in farming practices (Shears, 1984), rural development (Long, 1984) or enhancing literacy (Ouane, 1982; Ginsburg & Arias-Goding, 1984) and health (Byram & Kidd, 1983) programme. Thereon variances in radio delivery have been observed with the most recent being interactive radio programmes. The Farm Radio International (2015) which is a pioneer in farmer education over the radio, provides support for over 400 radio broadcasters in 38 different African countries. Examples are Farmer Voice Radio of Uganda, Dzimwe Community Radio of Malawi and Radio Ada of Ghana.

2.2. Interactive radio instruction (IRI)

Interactive Radio Instruction (IRI) is a DE medium which extends radio broadcast from primarily being a tool to widen access to a means of emphasizing active learning and improving educational quality and teaching practices. The key difference and success of IRI learning systems compared to broadcast radio has been the active learning pedagogy that is used in the design of IRI broadcast series which is incorporated into every script. The approach is interactive because students respond to radio prompts and interact with materials and peers at the radio's prompting (Anzalone & Bosch, 2005). Instruction is scaffolded across a series of episodes. Short experiments using locally available materials are devised and completed by teachers and students between broadcasts (Gaible & Burns, 2005). It started in the early 1970s by a team from the Stanford University with the support of USAID[2] to teach mathematics in Nicaragua. IRI has been found to have a significant impact on improving learning gains among its participants of diverse ages in diverse settings (Ho & Thukral, 2009). It also exhibits many best practices in professional development that provide demonstrable teaching and learning benefits (Bosch, 1997; Gaible & Burns, 2005). IRI has been used to teach maths, life-skills and early childhood education (EDC, 2009) in several developing countries and it has been found to have an impact on the comprehension and speaking skills (Nambair, 2010). Another variation of IRI is the Australian School of the Air (SOA) which has been successfully used to interactively connect farm children in the bush since 1948 to teachers and peers. Initially, it used the Royal Flying Doctor Service (RFDS) radio system network as a cheap interactive two-way communication to deliver audio courses to remote Australian regions. Later, high-frequency radio transceivers were used (SOA, nd).

2.3. Interactive audio instruction (IAI)

Interactive Audio Instruction (IAI) is a distance learning technology which delivers low-cost, culturally appropriate education via radio or audio technology such as CD/DVD. It is a highly effective tool to outreach deprived population who do have access to the conventional education system, including the rural poor and children with disabilities. It can be ideally used in unstable and conflict-affected regions (Rachel & Louge, 2015) by extending the reach of broadcast and interactive radio, both of which are highly vulnerable to broadcast interruptions. Delivery of these audio lessons are done through audio cassettes, CD/DVD-ROM, portable media players such as MP3 Players and podcast having the stop, pause, and replay features for enhanced interactivity. IAI allows learners to take control of their learning process and has demonstrated powerful results in diverse country contexts such as Honduras, Nepal, El Salvador, Indonesia, Zanzibar, Malawi, and Paraguay. IAI has shown to dramatically improve the quality of teaching and learning in a range of contexts across subject matter, age, gender and location (Ho & Thukral, 2009). According to EDC (2015), IAI has been used extensively in low-income, fragile, and conflict-affected countries in various domains namely primary and pre-schooling, teacher

[2] the U.S. Agency for International Development.

training, early childhood development, adult and civic education. However, despite the strong evidence base supporting IAI programs, scale up from pilot phase to long-run permanent phase is rare due to unavailability of long-term financing for such programmes.

2.4. Audio conferencing

Audio-conferencing (AC) is a synchronous telephony technology which allows meetings to be conducted simultaneously among several callers. It has long been used in DE to build learning communities among physically dispersed groups of students. It supports a broad range of learning styles and preferences (Macmullen, 2001). Professional development and healthcare programmes (Burns, 2011) are known courses having used AC for enhanced interaction to complement other modes of course delivery. There are two broad learning models which govern audio conferencing namely the "community of learners" and an "independent learning support" model (Anderson & Garrison, 1995). The learner based model focusses on extracting and developing knowledge from within the community rather than the mere exchange of content from teacher to students. On the other hand, the "independent learning support" model is more teacher directed and acts as a supplement to self-study courses. Besides calling individually, students can gather and be linked in small groups via the telephone. Mishra (2008) advocates convenience, cost, frequency which courseware is to be updated and the importance of telepresence as being the major advantages of AC. Cookson (1995) propones that telephone is the simplest and most accessible technologies used in DE to mentor and reach numerous students simultaneously. Audio conferencing adds a level of interaction in DE environment but at the cost of the learners' independence and flexibility. In addition, it requires a certain level of technical skill from both the teacher and student as well as access to relatively expensive resources. Besides, some developing countries (e.g. Ethiopia) have made the use of VoIP illegal with heavy penalties since this low-cost technology is disruptive to state-owned telephony companies. Therefore, educational conference call based on VoIP methods would not be permitted (Moskvitch, 2012). Hence, Macmullen (2001) suggests to carefully consider these trade-offs before committing to using audio conferencing as part of any educational programme.

2.5. Call centre/help desk model

In recent years, the service-centric **call centre model** has been extended and adapted in the DE sector to provide instructional services, collect survey data, enable fundraising and provide information to prospective students (Hitch & Macbrayne, 2003; Adria & Woudstra, 2001; Annand, Huber, Michalczuk, & Athabasca, 2002). It is used to answer course-related queries from off-campus students on a day-to-day basis. Doherty (2001) assesses call centre/helpdesk in education as a set of layered tiers namely i) *tier 0* as a web-based self-help interface for providing FAQ files, bulletin boards, conference and chat areas, ii) *tier1* being the first contact with students by call centre staff, (iii) *tier 2* as the contact with technical experts to whom questions are referred and (iv) finally *tier 3* being the academics for interactive sessions with students. Athabasca University has been using such system to dispense courses on a distant mode to more than 24,000 students annually. Besides, this system is widely used in developing countries mainly for providing agricultural information and advisory services to farmers. This model has the advantage of being accessible from anywhere and at any time with a maximum outreach as compared to traditional extension services. Call centre agents who are usually agronomists need to be at the back-end ready to respond to any queries. Examples abound like Kisan Call Centre[3] (KCC), IFFCO Kisan Sanchar[4] (IKSL) in India, *m*-Kilimo[5] of Kenya and National Farmer Call Centre[6] from Uganda (USAID, 2012). BBC Janala[7] is an English language learning system via phone calls introduced in Bangladesh. Besides, empowerment programmes like *Girl Connect* (Baker & Ibandan, 2017) in Nigeria, life skills in Bangladesh (YPSA, 2013) and sexual education in India (Sharma, 2009) are courses which are dispensed via call centers.

2.6. Knowledge/forum based approach

Knowledge/forum based approach in DE are platforms which connect students to an audio knowledge repository via phone calls using IVR and VoIP technology. Compared to call centre model, this system is automated and operates without the help desk tiers. Users navigate directly in the directory repositories via IVR prompts. Agropedia and vKVK (agropedia phase2) projects, developed by IIT-Kanpur, provide a wiki-type platform (Agropedia, 2008; Venkataraman & Prabhakar, 2014), enabling a digital ecosystem connecting KVKs with farmers through the internet, mobile and IVR technology. Avaaj Otalo is a forum based system, developed in collaboration with IBM and Development Support Center NGO for farmers to access relevant and timely agricultural information over the phone (Patel et al., 2008). Farmers can dial a phone number, navigate through simple audio prompts, record questions, review and respond to queries by other farmers, or access content published by agricultural experts and institutions. It has been a major success since its launch.

[3] http://www.e-agriculture.org/content/kisan-call-centre.
[4] http://www.iksl.in/.
[5] http://www.e-agriculture.org/content/m-kilimo-helpline-kenyan-farmers.
[6] http://www.naads.or.ug/data/sdmenu/41/National%20Farmer%20Call%20Centre.html.
[7] http://www.bbc.co.uk/mediaaction/where-we-work/asia/bangladesh/bbc-janala.

2.7. Research and approach on integrating voice in learning management system

With the advent of VoIP, IVR and open source PBX technologies, several systems have been implemented using voice calls to dispense educational message. Mobile Kunji[8] and Mobile Academy[9] are IVR Based systems supported by BBC Media Action and Gates Foundation which aims at persuading families in Bihar in adopting positive health practices. Through simple phone calls, people can access valuable health information. Similarly, Capacity Plus[10] project implemented an m-learning system using a combination of IVR and SMS text messaging to deliver training on family planning in Senegal for counseling, managing of contraceptive side effects and to dispel misconceptions (Gilroy et al., 2015). Learning through Interactive Voice Educational Systems (LIVES) is a push based voice learning system developed by the British Columbia University. The system calls the students at a scheduled time for course delivery (Vuong et al., 2010). Motiwalla (2009) proposes a voice-enabled interactive service (VòIS) architecture, implemented on IVR and voice recognition technology, for elearning system. He then evaluated the system with blind students from higher education institutions in the USA with a very positive outcome. Garcia et al. (2010) propose a "Voice Interactive Classroom", which is a middleware approach for cross-platform and multi-channel access to internet-based learning that can be reused and integrated within various elearning platforms.

3. Critical appraisal of existing audio learning system

The aim of this section is to provide a critical appraisal of the discussed audio learning systems using several variables identified to assess these audio technologies. Understanding and evaluation of these existing technologies in terms of adoption, support and effective learning will help in identifying shortcomings and gaps which should be addressed. Evaluation criteria for audio only learning platforms do not exist. Nevertheless, over the years, there have been several methodologies and models which have surged for selecting proper media for DE, evaluating multi-modal DE learning systems and Virtual Learning Environment (VLEs). This section overviews those different models of evaluation and proposes a set of criteria for appraising audio technologies used in DE.

3.1. Overview of evaluation methods, criteria and models from research literature

Daunt (1998) proposes four strategies in choosing a proper media for DE namely a) establishing the need and then choose technology, b) looking at the range of technology, c) include users in the selection process and d) consider the needs of the learners. Paquette-Frenette and Larocque. (1995) propose the selection of technologies which are easiest to use according to the following criteria: acquired competencies in the technology, least expensive to operate and maintain, easiest to network with for group work, most interactive in real time and easy to integrate with existing installations. Hawkes (1996) defined four criteria which can be used while choosing learning technologies namely Technical, Instructional, Organizational and Ethical criteria. Moore, Lockee, and Burton (2002) discuss how to conduct summative evaluations in implementing DE programs by evaluating their effectiveness taking into consideration the technology, student, faculty, learner and organisation.

Multi-criteria decision-making (MCDM) methods are popular and widely used by researchers. It is a valuable tool that helps in complex decision-making process by choosing the best among several pre-selected alternatives. Zaied (2005) enumerates nineteen (19) independent criteria in the technology selection evaluation process and makes use of a weighted criteria matrix as a valuable decision-making tool to evaluate the different technology medium used in DE. Shee and Wang (2008) provided a methodology for a simple, flexible and effective way to analyse and choose Web-based eLearning systems and identify necessary improvements to allow a higher level of e-learner satisfaction to be achieved, hence increasing the level of system acceptance and continued use. Kurilovas (2005) proposed a quality evaluation method suitable for the multiple criteria evaluation (decision making) and personalized Learning Management Systems (LMSs). The *internal quality* and adaptation *quality in use* evaluation criteria were applied on the LMS technology, analysed and incorporated into the comprehensive quality evaluation method. Besides, the LMSs parameters were further investigated and applied to personalise learners' needs.

Bates (2005) developed the ACTIONS model as a tool for decision-making process in technology investment and media selection for course delivery. ACTIONS stands for ***A**ccess, **C**osts, **T**eaching* and *Learning, **I**nteractivity* and *user-friendliness*, ***O**rganizational issues*, ***N**ovelty, **S**peed*. The SECTIONS model which stands for **S**tudent, **E**ase of use, **C**ost, **T**echnology, **I**nteractivity, **O**rganisation, **N**ovelty and **S**peed was an improvement of the ACTIONS model which made an oversight of the *students* and *ease of use* aspect as a decisional criterion (Bates, 2016). It was important to look at the targeted group of students taking into consideration their differences in learning style and technological literacy in the course design process. Besides, *Ease of Use* was extracted from Interactivity component in the ACTIONS model and proposed as a criteria on its own in the SECTIONS model to demonstrate the technological comfort provided. CASCOIME outlines eight practical guidelines in evaluating and selecting new technology medium for distance and online education targeted towards minority groups and developing regions namely **C**ost, **A**ccessibility, **S**ocial-political suitability, **C**ultural Friendliness, **O**penness, **I**nteractivity, **M**otivational value and **E**ase of Use (Patsula, 2002).

[8] http://msbcindia.org/mobile-kunji/.
[9] http://www.livemint.com/Industry/DZYdqthGZEDMJfGxdds8NN/Making-healthcare-information-accessible-through-a-phone-cal.html.
[10] http://www.capacityplus.org/.

Table 1
Value range for the TOL evaluation model.

Values	Description	Values	Description
0	Absence of such features	**4–7**	Features adequately represented
1–3	Features poorly represented	**8–10**	Features well represented

3.2. Proposed criteria for evaluation of audio learning systems

Several evaluation models have been discussed in section 3.1. Some are used for technology evaluation (Bates, 2005, 2016; Patsula, 2002; Zaied, 2005), while others look at it from the learner perspective (Kurilovas, 2005; Shee & Wang, 2008). However, none of these provide a holistic evaluation of the audio learning systems. This section proposes the TOL evaluation model which provides a comprehensive list of evaluation criteria to be used while evaluating audio learning systems from a **T**echnology, **O**rganisation and **L**earner point of view as shown in Table 3.

The *technology* criteria evaluates the development platform of such system in terms of their architecture, performance, ability to sustain simultaneous users without a drop in quality, scalability, robustness and portability. It then looks at factors such as interoperability, accessibility, interactivity and their capability to manage, monitor and assess students under the same platform. The *learner* criteria look at the extent to which users can take ownership and control of their learning process through easy to use and intuitive interface, personalisation, customization and interactive features. Besides, it takes into consideration the learner community aspect which is an integral part of the learning process. The *organisation* criteria look at the management aspect of such system in its ability to provide an all-in-one integrated system for the management of students, course and exams. It also evaluates the organizational capabilities of institutions to put in place, maintain and train staff accordingly over such systems. Besides it accounts for the capital, maintenance, development and day-to-day running cost of such systems. Finally, it looks into instructional design aspects of the audio course being delivered.

The detailed criteria under each category are listed in Table 3. Next to the criteria is the *Value column* for each of the Audio Learning Systems to be evaluated. The values range from 0 to 10 and are described in Table 1 as follows:

These values can be subjective and expressed as a personal judgment or a mean value derived from a survey with professionals in the field. The *Total* row sums up the score obtained under each heading for comparison purpose in the evaluation process.

Evaluation of a particular learning system can be carried out by introducing a value column in the table. Table 3 evaluates six identified Audio Learning Systems with their respective abbreviations as per Table 2:

3.3. Evaluation of the audio learning systems

This section evaluates the different aspects of existing audio learning platforms by using the proposed TOL evaluation model as per Table 3. This process will shed light on the gap and weaknesses which should be addressed while implementing an Audio MOOC system. It is to be noted that a subjective rating based on the author's opinion has been used in this evaluation process and these are further elaborated below.

3.3.1. Technology perspective- architecture and implementation

3.3.1.1. Platform. BR and IRI are based on radio technology while AC, CC and KN are implemented on telephony infrastructure and IAI uses interactive media. These technologies have been around and fine-tuned over decades and proven in terms of stability, robustness and security with reasonable performance optimisations. BR by definition is a fully scalable system at no additional cost. IRI depends on teachers and classrooms and any increase in students will be dependent on the mentioned variables. For IAI, any additional student means only the production of an additional student pack. As for AC, CC and KN, since they are based on telephony infrastructure, catering for surges in calls depends on the extent the system can *scale up, out* and *down*. Radio and telephony systems are closed and proprietary systems with mostly pre-programmed hardware. Hence, these systems are not as flexible as software-based technologies with no possibility of multiple installations on a single platform or portability across platforms. Besides, since they are platform dependent, integration and interoperability with other components and platforms might not be straightforward.

The overall design and architecture of the discussed audio learning systems are restricted to the technology. Besides such technologies do not register and authenticate users. Hence, there is limited possibility of adapting and personalising the system design to the learner's requirements and customizing contents delivery according to their learning needs and styles. Basic and predefined user interface is provided whether for radio (tuning of radio stations) or telephone calls via keypad input with no possibility of

Table 2
Audio learning systems abbreviations.

Audio Learning Systems	Abbreviation	Audio Learning Systems	Abbreviation
Broadcast Radio	**BR**	Audio Conference	**AC**
Interactive Radio Instructions	**IRI**	Call Centre	**CC**
Interactive Audio Instruction	**IAI**	Knowledge-Based System	**KN**

Table 3
TOL evaluation model for assessing audio learning systems.

	BR	IRI	IAI	AC	CC	KN
Technology Perspective – Overall architecture and implementation						
Platform						
Scalability	10	6	7	6	6	6
Modularity of the Architecture	3	3	3	3	3	3
Multiple installations on a single platform	0	0	0	0	0	0
Reasonable performance optimisations	7	7	7	7	7	7
Security	7	7	7	7	7	7
Robustness and Stability	7	7	7	7	7	7
Installation, Dependencies and Portability	0	0	0	0	0	0
Adaptability (Customization)	0	0	0	0	0	0
Total	**34**	**30**	**31**	**30**	**30**	**30**
Interoperability						
Straightforward Integration	2	2	2	2	2	2
LMS Integration	0	0	0	0	0	0
Total	**2**	**2**	**2**	**2**	**2**	**2**
Accessibility						
Convenience – Anytime, and anywhere	3	3	8	8	8	8
Ease of Dissemination – Easily deployed	10	8	7	7	7	7
Availability of technology infrastructure	10	10	8	8	8	8
Outreach to a wide enough audience	10	8	7	7	7	7
Access to energy for powering device	7	7	7	7	7	7
Total	**40**	**36**	**37**	**37**	**37**	**37**
Interactivity						
Timely and quality feedback	0	8	5	8	8	7
Learner-Learner interaction/feedback	0	8	0	6	6	8
Learner-Instructor interaction/feedback	2	8	5	8	8	8
Course Navigation	0	0	10	4	4	4
Total	**2**	**24**	**20**	**26**	**26**	**27**
Student Assessment, Monitoring & feedback						
Student registration	0	0	0	2	0	6
Assessment Capabilities	0	0	0	0	0	0
Performance Monitoring	0	2	0	0	0	3
Learner Tracking	0	0	0	0	0	0
Feedback on Performance	0	6	0	6	6	6
Total	**0**	**8**	**0**	**8**	**6**	**15**
Technology Total (T)	***78***	***100***	***90***	***103***	***101***	***111***
Learner Perspective						
Learner Interface						
Ease of Use	8	8	8	8	8	8
User Friendliness	7	7	7	7	7	7
Ease of Understanding	8	8	8	8	8	8
Operational Stability	10	9	10	8	8	8
Interactive	0	8	8	7	7	7
Course Navigation	0	0	10	4	4	4
Total	**33**	**40**	**51**	**42**	**42**	**42**
Learning Community						
Ease of discussion with peers	0	8	0	7	7	7
Ease of discussion with teachers	2	8	2	7	7	7
Ease of exchanging learning with peers	0	8	0	5	5	9
Timely and Quality feedback	0	8	0	7	7	7
Total	**2**	**32**	**2**	**26**	**26**	**30**
Personalisation						
Ability to control the learning process	0	3	8	5	5	5
Ability to record the learning performance	0	0	0	0	0	0
Total	**0**	**3**	**8**	**5**	**5**	**5**
Learner Total (L)	***35***	***75***	***61***	***73***	***73***	***77***
Organisation/Institution Perspective						
Organisation						
Organisation and Institutional requirements to provide stability and support	7	7	7	7	7	7
Staff Training	7	7	7	7	7	7
Total	**14**	**14**	**14**	**14**	**14**	**14**
LMS Support and Student Monitoring						
LMS Support	0	0	0	0	0	3

(*continued on next page*)

Table 3 (*continued*)

	BR	IRI	IAI	AC	CC	KN
Technology Perspective – Overall architecture and implementation						
Course Management	0	7	7	6	3	5
Exam Management	0	7	7	3	3	0
Performance Monitoring	0	7	3	6	3	3
Feedback on Performance	0	7	3	6	6	5
Total	**0**	**28**	**20**	**21**	**15**	**16**
Cost						
Fixed costs (Start-up/Capital/Administration costs)	1	8	5	7	9	9
Variable costs (Student support services/course delivery costs)	0	5	3	5	5	5
Course materials costs (Course design/production costs).	4	5	5	5	5	5
Development	4	5	5	5	5	5
Delivery	0	5	5	5	5	5
Maintenance Costs	5	5	5	5	5	5
Total (TC)	**14**	**33**	**28**	**32**	**34**	**34**
Inverse Total (60-TC)	**46**	***27***	**32**	**28**	**26**	**26**
Audio Pedagogy						
Adapted Instructional Design	7	7	7	5	5	5
Adapted Audio course development to technology	5	7	7	3	3	5
Total	**12**	**14**	**14**	**8**	**8**	**10**
Organisation Total (O)	***100***	***158***	***142***	***138***	***126***	***130***
Grand Total (T+O+L)	***213***	***333***	***293***	***314***	***300***	***318***

adapting and customizing to suit learner needs.

3.3.1.2. Interoperability and LMS support criteria. The technology used in these learning systems are mostly closed and proprietary. They are managed by experts and any need for information exchange, extension and adapting the system will need to be done by the authorized technology vendors. Any move towards interoperability with other systems or publishing interfacing APIs for development of interconnected application necessitates a huge effort. Besides, since such technologies initially were not conceived for learning, they do not provide LMS support with no proper framework for learning life cycle in terms of content creation and dissemination, content customization to suit learner needs, learner management, monitoring and tracking. This explains the low score attributed to them in Table 3.

3.3.1.3. Accessibility. Radio, telephones and interactive media (Cassette, CD/DVD) are tested technologies accessible anywhere, anytime and are affordable by everyone due to their decreasing cost, even to the poorest. Radio technology covers almost all regions as compared to telephone. Both technologies can access a wide audience but since radio is a broadcast service everyone can access it at no cost besides owning a radio, as compared to telephone/mobile phones which account for an airtime utilization cost. Since these technologies have been around for a while, everyone knows how to operate a radio, a mobile phone or interactive media players with a minimum learning curve. Courses are delivered in the learners' own language taking into consideration the cultural context, hence eliminating barriers to accessing online contents caused by illiteracy. Radio courses and audio conferencing, however, are less convenient than telephony technologies since they operate at a fixed schedule. On the other hand, CC and KN system can be utilized anywhere and anytime, although it depends on operating hours of call centers. Radio, IRI and AC operate at fixed schedule while CC, IAI and KN are more flexible allowing learning to take place anytime with more timely and quality feedback from instructors.

3.3.1.4. Access to energy/power sources. Access to power/energy is vital for operating the mentioned technologies. Provision of 24hr/day, constant and adequate power supply is still a restraining element in developing regions where these technologies are meant to be used (Action, 2014). Hence accessibility to power is a critical criterion included in our evaluation model. Radio based (BR, IRI and IAI) and phone-based (AC, CC, KN) approaches make use of low powering devices with the exception of smartphones and computers which are more energy greedy. Devices connected directly to power sources are more sensitive to disruption in power provision than those which are battery powered. In our appraisal, it is assumed that BR, IRI, IAI, AC, CC and KN makes use of battery power and can be charged before usage. Besides the score provided takes into account accessibility to alternative power sources such as wind-up radio, solar cell and wind up chargers for low powering electronic devices like audio/radio players, receivers and phones (Sponk. 1999; Mukherjee, 2015).

3.3.1.5. Interactivity. A major limitation of the discussed platforms is that their underlying technology does not allow learners to control the pace of learning in terms of navigation capabilities and interaction with the content as compared to IAI. AC, CC and KN allow interaction with the tutors or peers in the form of questions and answers (Q & A). They are usually used as a supplement to courses in response to queries on course materials. However, interaction with course materials itself is limited. Besides, interaction with peers and tutors are quasi-inexistent with BR and IAI, except for phone-in programmes. IRI is an interactive version of radio programmes providing face to face interaction with peers and teachers in the classroom, though the radio programme is broadcast at

a fixed schedule. On the other hand, telephony platforms (AC, CC, and KN) do provide interaction through phone calls with either peers or tutors but do not provide interactive control over content, which depends upon the tutor over the line.

3.3.1.6. Student assessment, monitoring and feedback. From the evaluation Table 3, it is obvious that none of the available systems provide any type of learner tracking and assessment from a technological point of view. BR, IRI, IAI, AC and CC do not allow some form of on-air/online registration and assessment except KN. These are conducted offline and not over the medium itself. Test, exam and assessment are done at some registered centers but not over the medium as compared to current LMS system with the possibility of instantaneous feedback. Besides, student performance monitoring is quasi-inexistent. Any form of tracking and analysis of students' performance and learning pattern cannot be provided by the existing audio learning platforms. Hence, this explains the poor score attributed to them in this section with the exception of feedback on performance whereby interactive systems were given a higher score.

3.3.2. Learner perspective

3.3.2.1. Learner interface. From a learner perspective, radio, telephone and interactive media have been around for a while and have proved to be stable technologies which are part of the everyday routine of people. Almost everyone knows how to use a radio and a simple dumb phone for mere phone calls, irrespective of their literacy level. Their ease of use, user-friendliness with a minimum learning curve makes them appropriate medium to access and educate the poor and the illiterate group. However, radio is a broadcast technology and does not allow any form of interaction either with the contents or with tutors and peers as compared to IRI. On the other hand, telephony technologies provide more interaction by connecting learners with tutors and peers for enhanced learning process. Nevertheless, it does not provide the learner control over the content as does IAI.

3.3.2.2. Learning community. A learning community is considered as an important factor in fostering the learning process through the exchange of knowledge and collaboration. It allows interaction among tutors and peers with timely feedback. Unfortunately, BR and IAI do not provide such learning community to its audience except for phone-in programmes and tutorial classes respectively. Telephony (AC, CC, KN) technologies allow for interaction with tutors and peers with the possibility of collaboration and feedback. IRI is considered to be more "community friendly" since it provides face-to-face interaction in classes with immediate feedback.

3.3.2.3. Personalisation. Personalisation is an essential component for effective learning. It denotes control over the learning process through interaction with the content, personalising the content to the learner's needs and the ability to monitor and record performance. None of the mentioned systems provide a platform for online/on-air monitoring and recording of the individual performance. With the exception of IAI, learners do not have control over their pace of learning and are rather passive with no possibility of personalisation of the content. Tutors in IRI and AC, since they provide face to face interaction may adjust teaching needs according to students' comprehension in class.

3.3.3. Organisation/institution perspective

3.3.3.1. Organisation. Adopting any system requires institutional support. Appropriate infrastructure needs to be set up to accommodate the technology. For Radio and IAI technologies, production environment needs to be created, accompanied by a whole team of researchers, academics and instructional designers. For telephony technologies, a robust telephony infrastructure needs to be set up to handle calls. Besides, faculties and staffs need to be trained to deliver over such medium.

3.3.3.2. Cost. One of the factors determining the adoption and utilization of a particular technology is cost. Cost in DE is broken down into four (4) parts namely the fixed, variable, development and maintenance cost. Fixed cost accounts for the start-up, capital and administration cost. Radio and telephony technology has a high capital cost. Nevertheless, for learning through broadcast radio and IRI, it is assumed that only the service of a radio station is utilized without the need for set up and huge capital investment. Besides, there is no variable cost associated with each additional student as compared to other systems. Radio programme is the cheapest system available since it involves only the development of the course content and the radio station fees. IRI though based on radio technology depends on classrooms, teachers and optional materials which account for a significant amount in its cost structure. AC, CC and KN are based on telephony technology which is equipment and hardware extensive and depends on the capability to service a number of users, beyond which, the system needs to be scaled to accommodate calling peaks. The development cost of audio content includes 1) research and pre-production involving subject specialists and instructional designers, 2) production which includes a recording studio, voice artists, instructional designer, 3) post-production involving editing and rework based on feedback and finally 4) broadcasting/transmission cost. Maintenance and overhead account for the cost of operating the system to keep it up to date and response to community needs. It is to be noted that in this section we calculate the inverse of the *total cost* which is lumped in the *Organisation total* since cost is considered to be a negative appraisal score as compared to others.

3.3.3.3. LMS support and assessment/exam. Learning Management System provides an all-inclusive platform for content creation, course, student and exam management. However, as seen in Table 3, with the exception of KN, none of the existing systems provide LMS support with the possibility to have online or on-air assessment, from a technological perspective. Nevertheless, from an organizational viewpoint, it is observed that institutions providing IRI, IAI, AC and KN do have Course and Exam Management systems with performance monitoring and feedback, though these may be offline and manual based. Real-time interaction systems were given a higher score on performance monitoring and feedback. Assessments and exams are done in the conventional way, i.e.

via exam centers. Besides, none of the learning systems devise contents according to LMS standard, hence limiting the possibility of interoperability among systems. BR, IAI and other telephony systems do not monitor students in terms of their learning and progress with no proper means of assessment over the medium itself, hence explaining the figures in Table 3.

3.3.3.4. Audio pedagogy. The effectiveness of audio learning relies on the quality of the content developed to optimize the use of a single sensory channel, i.e. our ears. It can be argued that BR, IRI and IAI over decades have fine-tuned and adapted their instructions to their respective medium and audience. They have been part and parcel of the DE arena, undergoing a structured and methodological approach in content creation and delivery, hence explaining their higher score. AC and CC have been mostly used as a supplement to DE mode, allowing students to interact with teachers to clear up doubts. They are mostly conversational and informal hence explaining their lower scores. It is to be noted that there are limited literature available on audio instructional design for the mentioned mediums. Structure, organisation, content, retention rate, ideal audio length, speech rate and motivational elements with respect to hese mediums are some of the research elements which are still unanswered. Besides, the types of learning which can be enabled over such medium needs further investigation.

3.3.4. Strengths and weaknesses of the identified audio learning systems

Table 4 provides a detailed assessment of the strengths and weaknesses of all the audio learning technologies discussed in this paper.

4. Research gap in audio learning technologies

The critical appraisal of the existing audio based technologies has provided an insight of the different strengths and weaknesses they portrait. Education via audio means has been used over decades, influencing the lives of people in many ways by providing information on various issues critical for making daily decisions. Radio offers one of the most practical, effective, powerful and low-cost means of communication to improve the quality of distance education in developing countries because of its broad coverage. Benefits of educational radio in developing countries have been recognized by educationists worldwide in motivating learners (Bates, 1990). Odera (2011) finds that radio technology is viewed by teachers as a useful tool for teaching and learning languages while Chandar and Sharma (2003) finds that radio can complement more traditional forms of educational delivery. Muhammad and Abbo (2010) finds that IRI has been very influential in the lives of nomadic population. On the other hand, telephony technologies like AC are effective in building learning communities made up of students from a wide range of backgrounds (Macmullen, P. 2001) and increased interactivity (Disbrow, 2008).

Though these technologies have contributed to educating the deprived, this evaluation has shed light on several limitations and research gaps which should be addressed to improve audio learning experiences via enhanced technologies available nowadays. This work identifies the following areas in audio learning which can be improved.

4.1. Learner interface

The presented technologies provide an established and stable easy-to-use interface since they have been around for long. Yet, the question which arises is whether such interface conforms to today's' learner requirements. From the critical appraisal, Radio and Telephony technologies provide limited interaction with content, radio being mostly one way with the exception of IRI as used in the Australian School of the Air which uses 2-way radio transceivers (SoA, nd). Controlling the pace of the content, with navigation capabilities, to suit individual learning style is beyond the scope of the existing audio learning system since they have been conceived for the mass. Again, customization of interface and content for a more personalized approach to learning is quasi-inexistent in the analysed existing systems.

4.2. LMS support

None of the presented systems provide LMS support and integration to depict the learning lifecycle in terms of user management, content creation and dissemination, learner tracking, progress and performance monitoring with the possibility of having online assessment and exam. With the actual audio learning systems, content creation and dissemination are two disparate avenues without an all-inclusive approach as provided by LMS, hence impacting on how quickly and effectively courses and contents can be created.

4.3. Flexible architecture

The architectures presented, though robust and stable, are not modular, portable and extensible since they are closed and proprietary systems which are technology depended with no support for LMS integration. Besides, the rigid architecture does not allow for customization to respond to organisation and learner needs. Future work will need to look at the development of flexible, scalable, adaptable and interoperable system which can easily adjust to changing needs in technology and easily integrate and operate with another system while maintaining stability and robustness even in service peaks.

Table 4
Assessment of the strengths and weaknesses of the audio learning technologies.

Audio Technology Type	Pros	Cons
Broadcast Radio (BR)		
Has been used for decades to empower the mass since it is considered as being the cheapest media for mass content delivery. (Jamison & McAnany, 1978; Chandar & Sharma, 2003; Chikasha, 2012)	• Wide outreach to the general public • Can be tailored to specific target audiences as well • No additional cost in delivering information to additional number of learners • Very effective for simple messages and slogans • Used to generate interest and awareness on particular subject topics • Low-cost technology as compared to others • Accessible and affordable by everyone and almost everywhere • Stable and robust technology	• Not flexible since radio programs are usually held on a fixed schedule which might not be convenient to some people. • It is a one-way medium with no room for interaction except for phone-in programmes • No control over the learning process • Depends on closed and proprietary software and hardware • No LMS Support, Integration and functionalities • Learning is technology-centered instead of student-centered
Interaction Radio Instructions (IRI)		
IRI involves the inclusion of radio programs, usually of a duration of 20–30 min, in class activities by well-trained teachers. It ensures standardization of courses in a well-structured manner and these are broadcast within fixed schedule regularly throughout the year (Bosch, 1997; Gaible & Burns, 2005; Thomas, 2001).	• High-quality standardized materials developed and produced using clear principles of instructional design. • Structured course with trained teachers. • Highly interactive and involves frequent student activities in response to the programme material. • provide a good social presence for effective education • supported by specially prepared printed materials for the students • Like BR, technology is accessible and affordable • Stable and robust technology	• Radio programmes are broadcast at fixed times schedules, hence does not provide flexible learning. • Students do not have control over their learning since the pace of radio is dictated by the broadcasters. • Does not provide interaction capabilities with the medium. However, this is compensated by the teacher. • Involves cost of school setups • Additional students depends on teacher to student ratio • No LMS Support, Integration and functionalities
Interactive Audio Instructions (IAI)		
IAI is used by almost all institutions providing a form of DE as a supplement to print materials. There are several IAI technologies which include Audio-Cassettes, DVDs/CD-ROM and Podcasts (Ho & Thukral, 2009).	• Target specific audiences, particularly attractive to young and technology people. • Flexible. Can learn anytime, anywhere and as many times since there is no time restriction as compared to BR. • Highly interactive. Provide a higher level of control over the learning process due to the provision of navigation capabilities (fast-forward, rewind, start and stop) which is not the case for broadcast media. • Technology is accessible almost everywhere. • Stable and robust technology	• Does not provide community/peer interaction which is essential in the learning process • Students should possess the appropriate hardware/players which might not necessarily be affordable to everyone • Requires specific hardware and software • Is relatively more expensive to produce, duplicate and disseminate as compared to BR. • Any additional number of students implies an additional cost of production and delivery. • No LMS Support, Integration and functionalities
Audio Conference		
Audio conferencing is a well-established teaching technology, accessible and flexible which is mostly used in Canada, India and Australia. It is particularly useful for the homebound or remote students and where there is the nucleus of distance learning (Ogar, William, Okenjom, & Godian, 2016). It is most effective for interactive work and discussion (Macmullen, 2001).	• Targets a specific group of learners/audience at the same time • Allows interaction between teachers and students, hence providing a sense of social presence which is essential to effective education • Allows interaction in a live format with large groups of people • Builds learning communities, even where the community is physically dispersed and made up of students from a wide range of backgrounds. • Best suited to interactive work, where tasks are based on the verbal exchanges between participants. • Audio-conferencing is still a superior means of synchronous communication in a learning environment compared to online chat. • Convenient when educational materials are updated very often • Stable and robust technology	• Requires a certain level of technical skill from both teacher and student to use the audio conference equipment. • Requires relatively expensive resources and equipment • Needs adequate ICT support, induction and setting up. • Not scalable and cannot outreach the mass, but only to a limited targeted audience. • Any additional students will involve an additional cost and is subject to the number of simultaneous users the audio conferencing tool can support • Is dependent on telephony connectivity, which certain deprived regions do not have • Technology might not be accessible and affordable by everyone and everywhere • No LMS Support, Integration and functionalities • Learning is technology centered instead of student-centered
Call Centre/Telephone approach	• Highly interactive.	

(*continued on next page*)

Table 4 (*continued*)

Audio Technology Type	Pros	Cons
One of the simplest and most accessible technologies used in distance learning to mentor students. (Cookson, 1995).	• Provide an element of social presence. • Can target a specific audience. • Learning on the move, anywhere. • Flexible. Can learn anytime within the call centre operational time. • Stable and robust technology	• Usually used as support medium for Q & A but not for courses • Anytime learning is limited to the call centre operational time. • Rather individualistic learning • Calls might be expensive and not affordable by everyone. • Dependent on telephony technology which might not be available in remote areas. • Scalability of system depends on hardware for simultaneous call and number of tell agents at the backend to respond to queries • No LMS Support, Integration and functionalities • Learning is technology centered instead of student-centered
Knowledge-based/Forum/Voice Mail Provides an interactive forum for discussion between students and teachers through asynchronous discussion/bulletin boards. Besides, it allows access to a repository of knowledge via phone calls and is usually suitable for Q & A. Examples of such systems include Forums, Voicemail and Online Knowledge systems. (Macmullen, 2001).	• Flexible. Can query the system anytime but the response might not be instantaneous. • Learning on the move, anywhere via phone calls. • Automated system with no tell agents as in Call centre • Less costly than call centers • Provide an interactive forum for discussion between students and teachers through asynchronous discussion/bulletin boards. • Eliminates the need for real-time participation, increases learner flexibility and expands the options for interaction and discourse as compared to Audio Conferencing. • Stable and robust technology	• Usually used as a supporting medium for learning by responding to students' queries. • Scalability of system depends on hardware for simultaneous call and number of teleagents at the backend to respond to queries • Dependent on telephony technology which might not be available and accessible in remote areas • Asynchronous technology and does not provide real-time interaction • No LMS Support, Integration and functionalities • Learning is technology centered instead of student-centered.

4.4. Audio pedagogy

Shee and Wang (2008) noted that learners place great value on system content and it was a critical non-technical aspect. Hence it denotes the importance of incorporating proper and effective pedagogy practices in developing audio materials taking into account the cognitive aspects of learners and the underlying technology to be used, which existing audio learning system sparsely consider. There are no proper audio-only instructional guidelines on how to create effective audio learning content to captivate, motivate and retain the attention of learners, which need to be further investigated.

4.5. Learning community

A learning community allows interaction among peers and instructors with proper and timely feedback. The telephony technologies visited do provide such kind of interaction especially AC, CC with real-time interaction while forum provides deferred interaction. Patel et al. (2008) did significant work in developing a forum based system over the phone to provide timely agricultural information. Yet, these interactions are not formalized and registered in the learning process unlike e-learning platforms which account for chat and forums with proper mechanisms to promote a learning community.

5. Conclusion

The evolution of DE to MOOCs resulted in an entire shift to a new paradigm, from standardization of education (Peters, 1994), being technology focused, to a more learner-centered approach to education. Audio has long been used as a supplement and supporting medium to the DE mode, understating its potential to becoming a full-fledged mode of delivery by itself. Recent literature reviews denote a lack of comprehensive evaluation of audio technologies in use and deployed for distance learning. Besides, there is no formal/established evaluation framework for evaluating such systems. This paper, therefore, brings its research contribution by proposing the Technological, Organisation and Learning (TOL) evaluation model through a set of 50 criteria to analyse and assess existing audio learning systems. Besides, it identifies and provides a detailed description of several audio learning systems currently in use and categorises them under Broadcast Radio (BR), Interactive Radio Instructions (IRI), Interactive Audio Instructions (IAI), Audio Conferencing (AC), Call Centers (CC) and Knowledge/Forum Based.

The proposed TOL evaluation model identifies the strengths and weaknesses of each of the audio learning technologies in use. As

per our evaluation, it is observed that these audio learning systems have focused mostly on technology and mass communication, overlooking many other critical aspects to effective learning. Our research findings highlight several shortcomings they present to operate as a MOOC and provides proper recommendations to make audio-only an effective learning medium for the illiterate and the deprived. LMS support for an integrated learning platform based on a flexible architecture, which allows customization and self-paced learning, is quasi-non-existent. Interactivity is considered as a major weakness which hinders effective learning over the audio medium. Besides the study reveals the sparse use of audio-only instructional guidelines on how to create effective audio learning content to optimize learning over the respective technologies. Finally, a formalized form of collaborative learning as per existing elearning platform is unavailable. Hence, recommendations are in terms of learner interface, LMS support, audio pedagogy, a learning community and flexible architecture. This paper provides a framework for evaluating audio learning systems/technologies in view of adopting them for educational purposes. In addition, it can be a foundation work for the implementation of audio-only Learning Management Systems/MOOCs, as it is in our case.

6. Sponsors

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.compedu.2017.10.004.

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