Heliyon 7 (2021) e06595

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Breaking out: the turning point in learning using mobile technology

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ARTICLE INFO

Keywords:
YouTube
SAWBO
History of ICT
Public service learning

ABSTRACT

Despite considerable research on YouTube as a digital media platform, little research to date has quantified the device-type used to *access* that online media. Analyzing access-device data for videos on one YouTube video channel—Scientific Animations Without Borders (SAWBO), which produces educational content specifically accessible to low- or non-literate, poor, or geographically isolated learners in less developed areas of the world—the results identify the historical moments between 2015 and 2017 when mobile/smartphones, both globally and by region, crossed a tipping point to surpass all other ICT devices (including desktop PCs, laptops, and other Internet-accessing technologies) as the primary device-type for accessing SAWBO videos. Specifically, data from January 2013 to June 2018 obtained for SAWBO's YouTube channel were sampled to capture and distinguish the access device-type used and then summarized in broad global and regional categories. The tipping point, as the date where the percentage of views from mobile phones was equivalent to the percentage of views from computers, were also calculated globally and by region. Besides documenting this critical global-historical moment, the results also have implications for mass digital-messaging generally and mobile-based public service learning specifically.

1. Introduction

1.1. Diffusion of innovations

The invention of a new technology is not always followed by its immediate or widespread adoption (Rice, 2009; Tolba and Mourad, 2011). Often this takes time (Rogers, 2003), sometimes even a long time, and significant social changes. Thus, when Johannes Gutenberg created his movable-type printing press in 1439, that invention started a world-altering revolution in communication that opened up radically new potentials for the mass dissemination of information (Febvre and Martin, 1997; McLuhan, 2009) and contributed to the Protestant Reformation and the Enlightenment. However, another three centuries approximately would have to pass before a general reading public, in a sense similar to what we see today, began to emerge (Eagleton, 2004; Ellis, 1989; Tompkins, 1932).

In this way, sometime between the invention of the printing press and the working out of its revolutionary cultural alterations that we live with today, a tipping point was crossed after which mass communication—in the form of books, journals, periodicals, newspapers, and other mass-printed materials—became not just widely available but also *accessible* to a general reading public at large. Research links this greater accessibility to the increased leisure time and wealth among the rising bourgeoisie from the late-eighteenth century onward (Baldridge, 1994; Eagleton, 2004). Consequently, while "the countries of Western Europe moved from restricted literacy [among elites] to mass literacy" (Kaestle, 1985, p. 20) over three centuries, from 1600 to 1900, by the middle of the nineteenth century, a tipping point had been reached such that print literacy became a critical national metric and goal. Nevertheless, even this greater availability and accessibility did not guarantee access for everyone. Whatever the expressed aspirations for universal literacy, it overlooked or explicitly excluded certain demographics, including

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https://doi.org/10.1016/j.heliyon.2021.e06595
Received 9 November 2020; Received in revised form 30 December 2020; Accepted 23 March 2021

people of color, women, the poor, and people with disabilities (Gilmore, 1985; Keefe and Copeland, 2011; Lumsford et al., 1990; Rooke, 1980).

Similarly, while the origin of the Internet as a means for rapid communication between remotely located (government or university) computers has its roots in the 1960s, it would be roughly another thirty years before something recognizable as the Internet would emerge (Leiner et al., 2009). While this afforded another revolution in mass communication, the Internet reached a tipping point when it overtook US newspapers and even television as a primary source for news in 2008 and 2011, respectively (Pew Research Center, 2008, 2011). Also like print literacy, although Zurkowski (1974) first used the specific term information literacy in 1974, by 1987, it was being argued as the most central skill in the current Information Age (Kuhlthau, 1987). From then, information literacy received urgent attention as a crucial national metric and goal, especially with the emergent mass availability *and* accessibility of the Internet (Doyle, 1994; Spitzer et al., 1998). However, whatever the expressed aspirations for information literacy, its reliance on often unaffordable technologies (like home computers) excluded certain demographics and generated information literacy gaps (Eubanks, 2012).

Only more recently has the digital availability of the world-wide web actually reached genuinely world-wide proportions. From 2005 to 2019, for instance, while the percentage of Internet users among European and American populations roughly only doubled—from 36% to 77.2% and 46%–82.5%, respectively—in Africa, the Arab states, and Asia, the percentage has at least quintupled (ITU, 2019). Partly, this situation arises from the already considerable population in Europe and the Americas accessing the Internet, but the explosion of *access* outside of those regions also occurred due to the miniaturization of personal computers as mobile phones (Goggin, 2010; Ling and Horst, 2011; Parley, 2007). Comparing the increases in fixed versus mobile (cell-phone) broadband access in the developed and developing world from 2007 to 2019 (ITU, 2019), for fixed broadband usage, the developed world saw a 1.86-fold increase (from 18% to 33.6%) and an 5.5-fold increase in the developing world (from 2% to 11%). For mobile broadband access, however, the developed and developing world differed by a 6.4-fold versus a 75.2-fold increase (from 19% to 121.7% and 1%–75.2%, respectively).

These increases align with frameworks that recognize how an innovation's availability *and* accessibility play a critical role in that innovation's adoption (Ribot and Peluso, 2003; Rogers, 2003; Tolba and Mourad, 2011). Consequently, just as a tipping point for book readers with enough resources (of skill, time, and money) to read was reached, these days increasing numbers of people have the resources—e.g., digital awareness (Reddy et al., 2020), affordable data plans (Cable.Co.UK, n.d.), ownership or sharing-arrangements for SIM cards or smartphones (Amiri Sani, Boos, Yun and Zhong, 2014; Donner, 2007; Wyche et al., 2015), stable electrical infrastructures or solar-charging panels in rural or remote areas to keep phones charged (Almeida and Brito, 2015)—to access digitally available content. Paralleling the accessibility to books (and other print media), which did not guarantee access to everyone but positioned accessibility as a critical part of culture and citizenship (Sanya, 2017) beyond a certain tipping point, so has digital accessibility passed a tipping point to become a critical part of present-day culture and citizenship (Choi, 2016; Sanya and Odero, 2017)—without yet safeguarding access for everyone and thus inadvertently or deliberately excluding some. Indeed, Ribot and Peluso (2003) persuasively argue that providing availability without enabling accessibility represents a shortfall for any intervention; as such, availability with inadequate accessibility limits the reach of any diffusion of an innovation (Kee, 2017; Rice, 2009).

While the digital access data cited above would already seem to suggest that a tipping point has been passed for digital accessibility via mobile phones, it does not yet specify when or where or to what extent. For interventions to address transboundary or global-level issues (Ansell et al., 2010)—like COVID19 prevention, climate-change mitigation, or control of trans-regional pest epidemics (Bello-Bravo, Huesing, Boddupalli et al., 2018; Bryce et al., 2020; Cooley and Gleick, 2011)—failing to achieve a maximal degree of accessibility for such interventions harms everyone potentially. For this reason, to verify empirically whether and how we have passed a tipping point for digital accessibility will inform any future intervention efforts into other transboundary and global-scale (but also local) issues going forward. Equally, if mobile phones represent the most accessible form of digital literacy, this has significant implications for adult learning generally.

1.2. *Diffusion of digital access*

In the heady early years of digital development, digital technologies were heralded by the World Bank, UNESCO, and the OECD as a solution to global asymmetries in information (Burnett, D'Antoni, Johnstone et al., 2009; Ferroni, 1998; Johnstone, 2005; M. S. Smith and Casserly, 2006; White et al., 2011). Since then, an initial overenthusiasm for information and communication technologies (ICT) in development has dampened in the face of new asymmetries due to digital infrastructure, cost, accessibility, and digital literacy. Nevertheless, the promise of digital technologies remains.

Currently, the continuing and accelerating proliferation of access to digital and Internet infrastructures in virtually every corner of the world positions ICT educational videos and animations as more and more relevant for delivering knowledge to people of very diverse educational levels (Bello-Bravo and Pittendrigh, 2018; Nye, 2015; Reddy et al., 2020). The reach of this access, however, can be limited by several factors, including not only user costs, technological provider/user literacy, reliability of electricity, language barriers, and censorship (Bello-Bravo et al., 2019; Cassim and Obono, 2011; Fedorov, 2015; Gitau et al., 2010; Gulati, 2008; International Telecommunication Union, 2012; Nye, 2015), but also the availability and feasibility of different types of technological devices for accessing digital (Internet) infrastructure (Byrne-Davis et al., 2015; Rodríguez-Domenech et al., 2019; Selwyn, 2016). And while a growing body of literature has investigated and assessed the effectiveness of various ICT device delivery strategies, including tablets (Montrieux et al., 2015; Pruet et al., 2016; Viberg and Grönlund, 2017) and cellphones (Abbott et al., 2017; Bello-Bravo, 2017; Maredia et al., 2018), insufficient numbers of studies to date have quantified and compared access to online ICT educational content media by these device types (Zhou et al., 2014).

There is little doubt that online video consumption globally is increasing, particularly among younger demographics, and with a peak usage between one to four hours per week (Limelight Networks, 2018). Globally, this noted age gap is more pronounced for device type. That is, while computers and smartphones globally have a rough parity of access usage, younger demographics more often access online video content using smartphones (Limelight Networks, 2018). For educational ICT efforts in developing nation contexts, the fact that the number of Internet-accessible cell-phones exceeds other ICT access devices (tablets, PCs, laptops) by an enormous margin more or less mandates creating cell-phone accessible content (Bello-Bravo and Pittendrigh, 2018).

Among video platforms online, YouTube has the highest traffic, not only for viewing—approximately 5 billion videos per day—but also for uploading and downloading content, estimated at 300+ hours of video per minute (Limelight Networks, 2018; Omnicore, 2018). Unlike the age gap in users globally, on YouTube the 35+ and 65+ demographics are the fastest growing, often in order to find and view nostalgic content (Omnicore, 2018). Attracting as much as one-third of global Internet users overall, YouTube's mobile revenue and usage also continues to increase—there are currently over one billion mobile views per day (Brouwer, 2018)—while its parent company, Google, has stated its intent to use YouTube to drive its future growth (Reuters, 2017). Subsequently, to secure cell-phone access and full video watch times for formal and informal development-related educational ICTs on YouTube represents a potentially very wide distribution and knowledge transfer capability for that content.

Since 2011, Scientific Animations Without Borders (SAWBO) has been developing "mobile ESD" (mobile Education for Sustainable Development): an educational content delivery system of freely available, Internet-accessible video animations on a variety of high-impact educational topics translated accurately into over 200 languages and dialects. Using SAWBO's Deployer App, users with video-enabled cellphones can select, download, watch, and redistribute any of these videos. This is especially the case in developing nation contexts where cellphones are not only generally the most available digital access device available but are also the most technologically familiar (Aker, 2010).

This mobile ESD combination of elements affords the delivery of high-impact and mission-critical educational information to geographically remote locations, low- or non-literate users, and people of any age, gender, or socioeconomic status who are otherwise overlooked, marginalized, or would not have had access to the information (Bello-Bravo and Lutomia, 2016; Bello-Bravo, Lutomia, Madela and Pittendrigh, 2017; Bello-Bravo et al., 2019; Bello-Bravo, Lutomia, Songu and Pittendrigh, 2017; Bello-Bravo, Zakari, Baoua and Pittendrigh, 2018). To date, SAWBO has developed and shared educational animations via YouTube on more than 100 topics, in 200 languages and dialects, and that have been watched in more than 100 countries.

In this way, SAWBO's video channel on YouTube represents the kind of large-scale platform described by Chen et al. (2013) suitable for measuring the device type and video watch time of users who access educational ICT materials freely available on a major digital platform. However, because SAWBO's educational content is also specifically intended for low- or non-literate, poor, or geographically isolated people in less developed areas, access device type data from SAWBO's channel affords insights for educational content designers' efforts to deliver such content to these demographics.

Analysis of such data also further affords a window into any local or regional device type access specifics. For example, while computers edge out smartphones globally as digital access device type, local statistics can vary significantly; in India, for instance, smartphones exceed computers as the main digital access type, while in Germany, SmartTVs exceed smartphones (Limelight Networks, 2018). In contrast, in the United States, computers, smartphones, and SmartTVs all have roughly the same level of prevalence (Limelight Networks, 2018). Given that digital access device type measures vary significantly in developing nation contexts, to obtain a more accurate measure of the most prevalent access device type will inform efforts to more affordably and effectively create educational content delivery channels with increased odds of reaching their target audiences. Moreover, as digital access continues to advance further and further away from each tipping point, whether global or regional, this will have increasing impacts on information communication technology for development (ICT4D) across areas as diverse as online (YouTube) learning efficacy, collaborations for mobile-based learning, and how mobile-learners actually use available mobile learning (mLearning) (Aldenny et al., 2019; Husna et al., 2019; Troussas et al., 2020).

2. Materials and methods

This paper adopts a quantitative research approach, for how it "focuses on carefully measuring (or experimentally manipulating) a parsimonious set of variables to answer theory-guided research questions and hypotheses" (Creswell and Creswell, 2018**,** p. 234). Using data collected from the SAWBO YouTube channel, this study measures and identifies the tipping point globally and by region for the use of cell/smartphones as a mechanism for accessing educational content globally. By tipping point is meant that smartphones as the device access type surpassed other access device types as the device of choice.

Data from January 2013 to June 2018 obtained for SAWBO's YouTube channel using the Analytics API v2 were sampled quarterly to capture the access devices used and distinguished daily views from 250 different geographical regions. Analysis calculated data points (Equation 1) as central moving averages per Kendall (Stuart, Arnold, Ord, O'Hagan and Forster, 1994).

$$\widehat{Y}_n = \frac{Y_{n-i} + Y_n + Y_{n+i}}{11}; i = 1 \text{ } to \text{ } 5 \quad (1)$$

where $n =$ *date of observation;* if *n-i has no observation,* Y_n *will replace* $Y_{n\text{-}i}$, and if $n + i$ *has no observation,* then Y_n *will replace* Y_{n+i}.

To match access device and date of observation, the linear portion of data for each access device was straight-line fitted using Mathematica

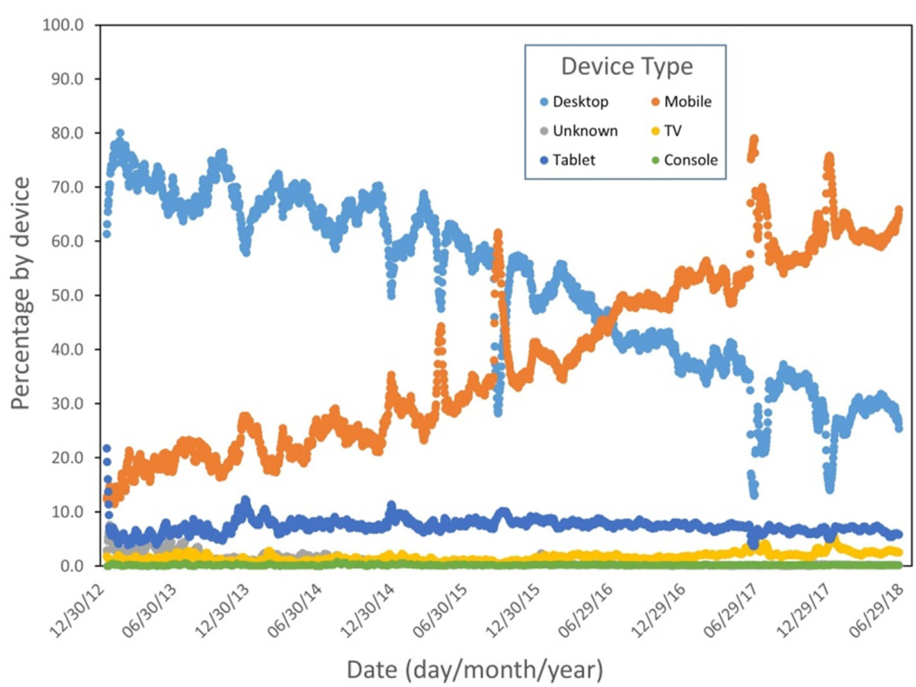

Figure 1. Use-comparison for six access device types globally. The x-axis is the date of viewing and the Y-axis the percentage of views by device.

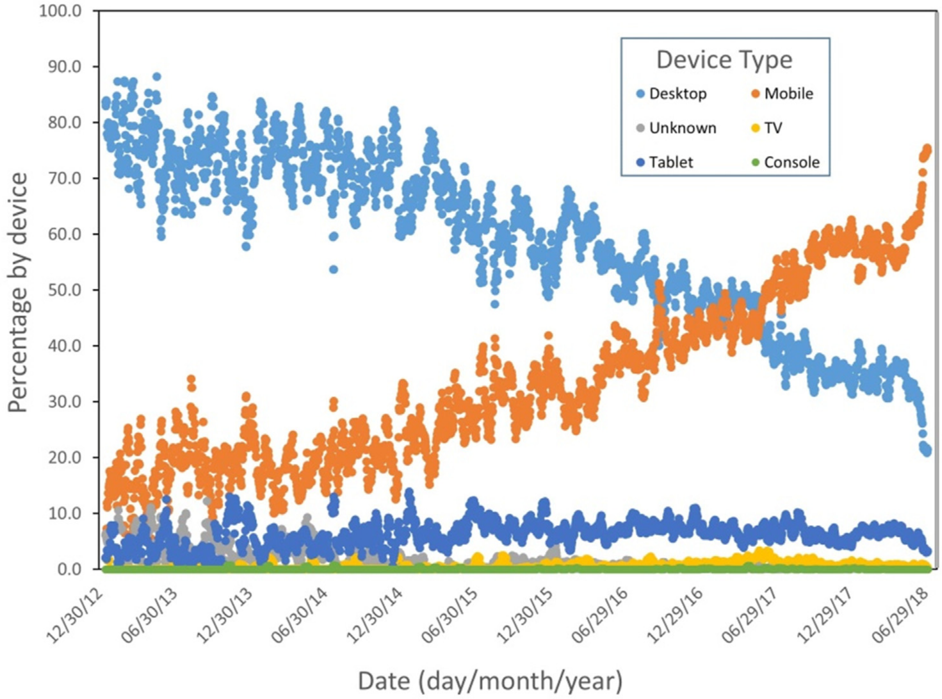

Figure 2. Access device use-comparison for Africa. The x-axis is the date of viewing and the Y-axis shows the percentage of views by device.

11.3's *fit* function, with the equivalence point (for access device and date of observation) calculated using the *solve* function. That is, for each region (North America, Central America, South America, Africa, Asia, and Europe), view percentages by mobile phone (Equation 2) and computer (Equation 3) were fitted to straight lines using (Stuart, Arnold, Ord, O'Hagan and Forster, 1994):

$$\widehat{Y}_{mobile} = a_{mobile}x + b_{mobile} \tag{2}$$

$$\widehat{Y}_{computer} = a_{computer}x + b_{computer} \tag{3}$$

Where $\widehat{Y}_{mobile}$ and $\widehat{Y}_{computer}$ calculate central moving average percentages of views by mobile phone and computer, respectively, x is the number of days since January 2013, and a_{mobile}, b_{mobile}, $a_{computer}$, and $b_{computer}$ represent the slope and intercept parameters. The tipping point—as the date where the percentage of views from mobile phones was equivalent to the percentage of views from computers—was calculated as given in Eq. (4) (Stuart, Arnold, Ord, O'Hagan and Forster, 1994).

$$x = \frac{b_{computer} - b_{mobile}}{a_{mobile} - a_{computer}} \tag{4}$$

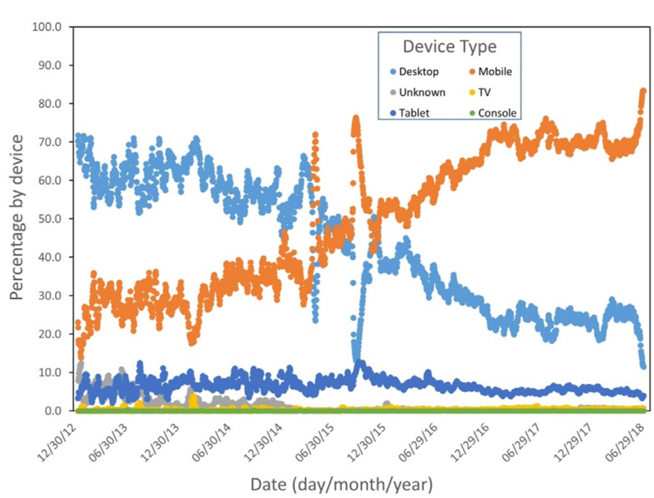

Figure 3. Access device use-comparison for Asia. The x-axis is the date of viewing and the Y-axis shows the percentage of views by device.

3. Results

Figures 1, 2, 3, 4, 5, 6, and 7 depict SAWBO video YouTube library access by six device types (desktop, mobile phones, tablets, televisions, consoles, and unknown) from January 15, 2013 to April 15, 2018 globally and by region.

3.1. Global trends show an increase use of mobiles phones

Access trends for SAWBO YouTube videos during the data period suggest the following. First, mobile devices (Android phones, although iPhones may be included in the numbers in some regions of the world) overtook desktop computers as the most popular device for accessing SAWBO videos in all regions. Second, tipping points by region occurred at different times; some areas were early adopters and others were late adopters. Third, some devices types always had low to negligible access use. For example, tablets have consistently remained around or below 7.8%, with Europe still at 12.5%, as access type. Similarly, televisions and consoles remain extremely low as access devices for watching, e.g., 0.0% for televisions in Africa and Asia, and 0.0% for consoles in all regions.

3.2. Crossover dates to mobile phones for each region

Initially, desktops were the first-preferred access device for watching SAWBO videos. Between 4 July 2015 and 26 August 2017, however, a tipping point was passed such that mobile phones became the first-preferred device for watching SAWBO YouTube videos in all regions. Asia was the first to cross this tipping point to mobile phones, followed by Central Asia, North America, South America, Africa, and lastly Europe

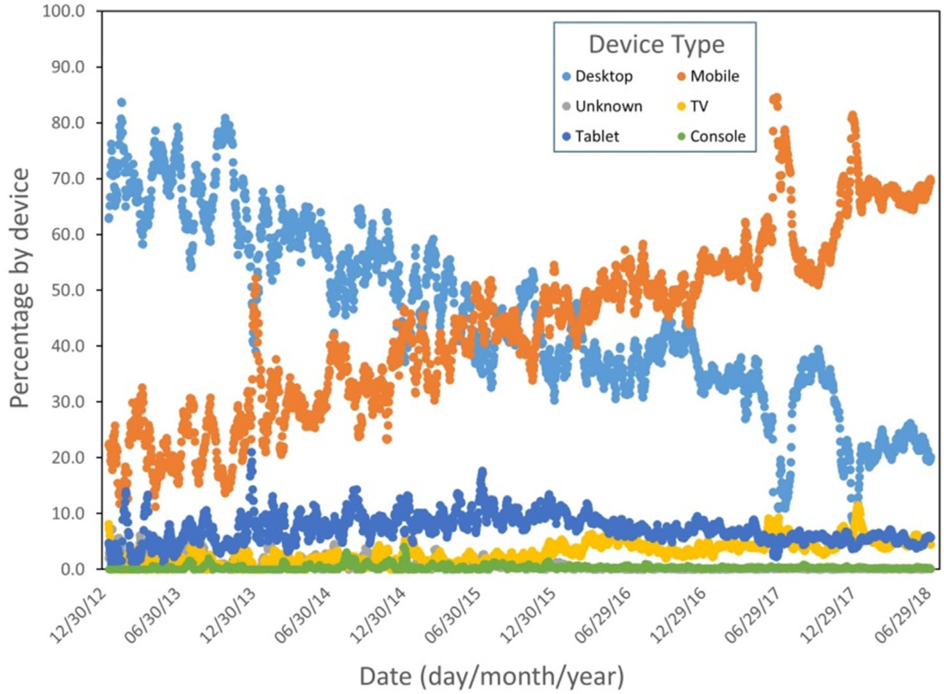

Figure 4. Access device use-comparison for Central America. The x-axis is the date of viewing and the Y-axis shows the percentage of views by device.

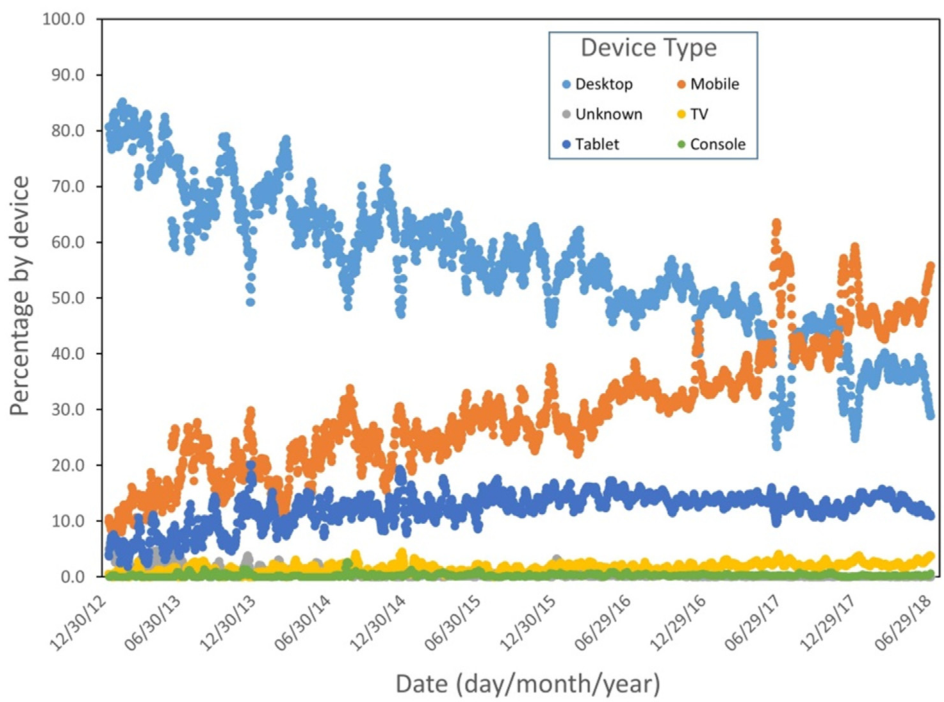

Figure 5. Access device use-comparison for Europe. The x-axis is the date of viewing and the Y-axis shows the percentage of views by device.

(Table 1). This agrees with data similarly showing a shift to mobile devices as the preferred delivery mechanism for public service learning in the fields of health, nutrition, food safety, and agriculture (Michel and Burbidge, 2019).

4. Discussion

The implications of this historic shift in device use are far-reaching. Information has become mobile and, as a result, a revolution in messaging and learning is underway. What were once inaccessible areas and populations due to restrictions in infrastructure and personnel have now become accessible due to the pervasiveness of mobile technology. Governments and international development organizations would do well to heed this shift and adjust their strategies accordingly. The most important focus of this shift is the ability to inform the public at large through public learning services (PSL). Especially in the information age, this ability is an essential driver of socio-economic development (Bógdał-Brzezińska, 2020; Brown, 2020; Calara, 2020; Davidson and

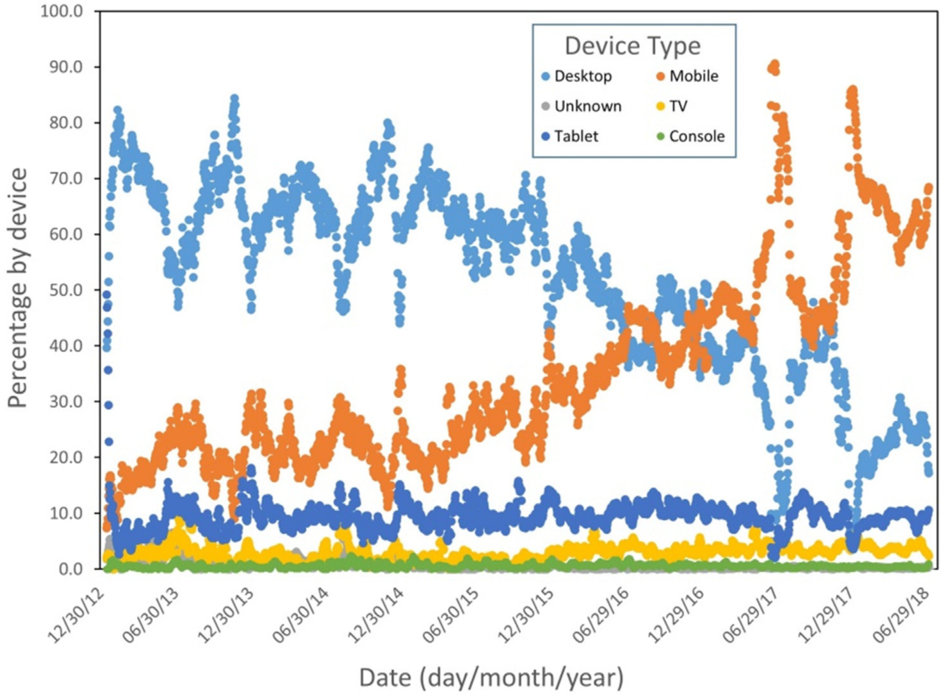

Figure 6. Access device use-comparison for North America. The x-axis is the date of viewing and the Y-axis shows the percentage of views by device.

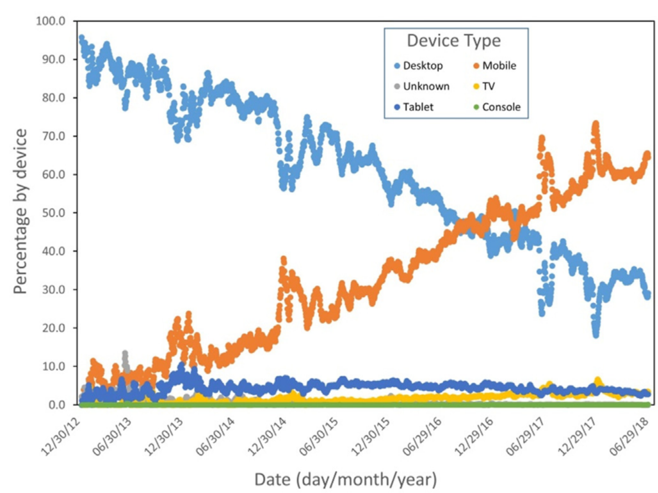

Figure 7. Access device use-comparison for South America. The x-axis is the date of viewing and the Y-axis shows the percentage of views by device.

Rees-Mogg, 2020; Morley et al., 2020). This shift toward enhanced PSL through the use of mobile technology is a harbinger of a new age in the democratization of information (Franco, Carvalho, da Costa Santos and Ventura, 2019; Hyun et al., 2020; Smith and Hanson, 2019; Yiyan et al., 2020). Failure to take advantage of these new possibilities in mobile technology-based PSL runs the risk of widening the digital divide within and between developing regions (Robinson, Schulz, Blank et al., 2020; Robinson, Schulz, Dunn et al., 2020).

Table 1. Crossover dates (Tipping Point) by continent.

Continent	Date
Asia	07-04-2015
Central America	11-01-2015
North America	10-22-2016
South America	11-28-2016
Africa	03-05-2017
Europe	08-27-2017

4.1. Accessibility

For both governments and international development agencies, PSL in the area of health, nutrition, food safety, and agricultural sectors rely heavily on the dissemination of important information to the right users at the right time (Bello-Bravo and Lutomia, 2016; Bello-Bravo, Lutomia, Madela, et al., 2017; Bello-Bravo et al., 2019; Bello-Bravo, Lutomia, Songu, et al., 2017; Bello-Bravo, Zakari, et al., 2018). This PSL has two functions: to avoid crises and to increase knowledge, skill, and productivity. The key to both of these functions is information delivery. Without it neither PSL goal can be achieved. Several different technologies have been offered as potential vehicles for information delivery, including traditional methods of extension education through extension agents, radio, television, and more recently tablets and laptops (Jones and Garforth, 1997).

While ICTs have had considerable impact (Aker, 2010), they have also fallen short of delivering the anticipated reduction in information asymmetries. Nevertheless, as clear from this study's data, the tipping point for mobile devices is decisive and most likely definitive, since there have been no changes in this emerging pattern since the mobile device replaced computers between 2015 and 2017 as the device of preference in all regions. Given the dramatic rise in the use of mobile devices for the types of public service information available through SAWBO videos, this trend suggests a clear indication that users globally are seeking “point of need” information from mobile devices far more than from any other form of ICT.

As such, the data imply at least a kind of reduction in the digital divide globally through increased mobile phone use, if only in terms of sheer numbers. For example, in Asia, mobile broadband 3G and above had become the dominant technology by the end of 2016, which opened access for 2.7 billion unique subscribers (GSMA, 2017). In terms of accessibility, the prevalence of social phenomena like phone sharing and

SIM swapping (Chiumbu, 2012; Wesolowski et al., 2012) further suggests that the total reach of digital ESD is greater than these unique 2.7 billion subscribers individually.

4.2. Education for sustainable development

This study has two principle implications for developing education for sustainable development campaigns and messaging. First, Brodersen et al. (2012) emphasize how online video consumption reflects the geographic locality of interest. They argue that users in close geographic proximity who exhibit similarities in dialect and culture can spread Web content through word-of-mouth social connections. Relatedly, the geographical locality of interest—and thus the dialect and culture of educational animations produced by SAWBO—can achieve this by creating "animated, linguistically localized, digitally accessible, and readily sharable cell-phone form of SAWBO's audiovisual video productions meet these two major criteria" (Rodríguez-Domenech et al., 2019, p. 1107).

Brodersen et al. (2012) also add that "understanding how and where users watch YouTube videos is important because it informs the building of predictable models of user interest to designing recommended systems" (p. 242). As such, although crossing the tipping point to Internet-accessible cellphones, more than tablets, PCs, or laptops, signals a call need for cellphone-friendly content (Bello-Bravo and Pittendrigh, 2018), successfully designing phone-based ESD applications involves more than simply porting existing digital materials into an App format (Rojas-Alfaro and Chen, 2019).

Second, the rise of mobile technologies presents several advantages for message developers of national-scale, public service-learning (PSL) (Eyler and Giles, 1999) as framed through the lens of digital mobile learning (Koole, 2009). In its broadest sense, public service-learning refers to "an organized educational experience that both meets needs of the community and fulfills learning objectives" (Steinke and Fitch, 2007, p. 24), which couples to mobile learning when it offers learners "greater access to relevant information, reduced cognitive load, and increased access to other people and systems" (Koole, 2009, p. 26).

In terms of push-pull mechanisms for public service information, mobile devices can leverage developments in the field of teaching and learning, particularly using the Framework for the Rational Analysis of Mobile Education (FRAME) model for mobile learning (mLearning), which describes the "process resulting from the convergence of mobile technologies, human learning capacities, and social interaction" (Koole, 2009, p. 25). Rooted in the Activity Theory of Kaptelinin and Nardi (2006), and work by Vygotsky (1978) on *mediation* and the *zone of proximal development*, FRAME addresses pedagogical issues related to "knowledge navigation and collaboration in learning" (Koole, 2009, p. 25).

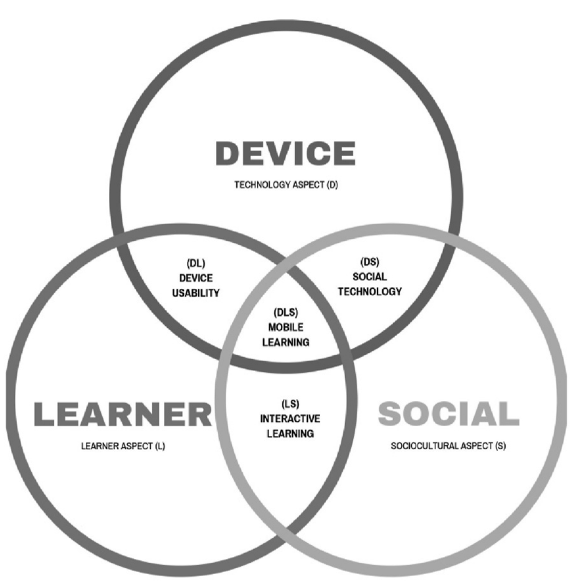

Figure 8. Model of optimal mobile learning. Source: Adapted from Koole (2009)

Optimal mobile learning occurs at the intersections of a device (D), a learner (L), and a social context (S) (Koole, 2009, p. 27; see Figure 8). Overlapping areas represent notions such as device usability (DL, or the device-learner interface), social technology (DS, or how well the device is socially "connected"), and social learning (LS, or how well the learner is connected to a broader community of practice). At the center is the point of optimal learning (DLS), where the device, the learner, and social engagement converge; hence, "by assessing the degree to which all the areas of the FRAME model are utilized within a mobile learning situation, practitioners may use the model to design more effective mobile learning experiences" (Koole, 2009, p. 27).

Applying Koole (2009) model to PSL, then, we find that several critical factors for optimizing PSL's potential with mobile devices for PSL, discussed below.

4.3. The device aspect

PSL, by definition, is for the public at large. Therefore, PSL must include the wide range of devices in use to make sure that public service content is available to the broadest array of users possible. This means that, especially in developing contexts where access to high-end, complex technology is rare, creators of content must take into account the total variety of devices in use. Factors to be considered, according to Koole (2009, p. 28), include the physical characteristics of the device (size, weight, keyboard style, right- and left-hand capabilities, and the like), the input capabilities (keyboard, light pen, pen/stylus, touch screen, trackball, joystick, touchpad, hand/foot control, and voice recognition), and output capabilities (screens, speakers or any other visual, auditory, and tactile output mechanisms), file storage and retrieval (storage on the RAM or ROM device or detachable, portable mechanisms such as USB drives, CDs, DVDs, and SD cards), processor speed (response rates; speed with which the device reacts to human input), and error rates (malfunctions resulting from flaws in hardware, software, and/or interface design). Moreover, the content must be retrievable and useable on the device. While reducing the technological complexity of some learning content may—in some cases—reduce the visual appeal of the educational content, the alternative is to fail to engage large parts of the public due to a lack of technical capacity. Although much effort goes into the "wow" factor when it comes to mobile content, for the public at large, keeping content delivery platforms as simple as possible best serves reaching the largest number of people possible (Kim and Cappella, 2019).

4.4. The learner aspect

The learner aspect considers "an individual's cognitive abilities, memory, prior knowledge, emotions, and possible motivations" (Koole, 2009, p. 29). It consists of the prior knowledge (cognitive structures already in memory, anchoring ideas, schema theory, conditions for learning), memory (techniques for successful encoding with the use of contextual cues: categorization, mnemonics, self-questioning, semantic & episodic memory, tactile, auditory, olfactory, visual imagery, kinesthetic imagery, dual coding, and encoding specificity), context and transfer (inert vs. active knowledge), discovery learning (application of procedures and concepts to new situation; solutions for novel problems), and emotions and motivations (feelings of the learner towards a task; reasons for accomplishing a task).

In this aspect, it is vital to consider the *timing* of PSL. PSL is most effective when motivated by an urgent concern. While curiosity and a desire to learn respond to the perceived importance of the message (Ping-ying, 2017; Wasserman, 2019), when placing PSL content, it is important that the timing of the placement considers the motivation of the learner to engage the content.

Recent examples can be gleaned from the COVID-19 crisis, in which the uptake of PSL differed relative to where countries stood in the progression of the outbreak. Uptake was much greater in countries where the pandemic was first making its incursion than in countries where the outbreak had been around for several weeks. Moreover, the ready-to-hand element of mobile phones (for accessing PSL) helps to make accessing any urgently timed messaging that much more convenient.

4.5. Social aspect

Finally, the social aspect consists of "the processes of social interaction and cooperation" (Koole, 2009, p. 31). Learning must be reinforced socially to be durable. Where social reinforcement is absent, the validity of a message is often abandoned. Koole proposes that the social aspect of learning consists of two components, conversation and cooperation (social constraints; maxims/rules: quantity, quality, relation, and manner), and social interaction (conversation as a cooperative activity, sharing of signs and symbols). In designing content for PSL, it is important to find or make available social "hooks" for newly acquired learning as demonstrated in Vygotsky's social learning theory (Vygotsky and Cole, 2018). Since in developing nation contexts—where PSL messaging is often conveying messages for the first time and communities of knowledge and practice may not be readily available to users—it is vital to implant a social component within PSL content. This means ensuring that, along with content, there are also connections made available through social media to larger communities of learning and practice (Caldwell and Cox, 2018; Chapple et al., 2018; Maher and Donaldson, 2017).

5. Conclusion

Overall, this research demonstrates that we have globally passed a tipping point such that mobile phones are now the dominant access device type for viewing SAWBO ESD videos, although all devices, e.g., mobile phones, desktops, tablets, and televisions in descending prevalence, obviously remain in use. The data also supports that between 2015 and 2017, a time-differentiated shift by region (North America, Central America, South America, Africa, Asia, Europe) occurred toward the use of mobile phones for viewing SAWBO ESD videos.

This study provides a grounding for much needed future research into YouTube video access device-types by geographical setting. First, future studies could identify videos by topic and device type to analyze high and low use-spikes, particularly in response to local (video-related) events; video watch-time or downloading by device (i.e., by mobile phone or desktop) could disclose use patterns as well. Second, follow-up studies could broaden the data-corpus analyzed to identify or measure locally triggered watching of videos.

Third, data in this study necessarily assumed a one-to-one correspondence between the access device and an individual user. Given social practices of phone co-ownership, joint use, and borrowing, further research could develop ways to more exactly measure the numbers of people reached; for example, could multiple watching of the same mobile video be related to multiple users accessing the same content? At its broadest, further research could link to current efforts to optimize the device, learner, and social aspect of mobile learning to ensure that any mobile ESD/PSL messaging aspires toward reaching 100% of the demographic that would benefit from the messaging.

Declarations

Author contribution statement

Julia Bello-Bravo, Ian Brooks, Barry Pittendrigh: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Anne Namatsi Lutomia, Jeremy Bohonos, John Medendorp: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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