Scholars on Soap Boxes: Science Communication and Dissemination via TED Videos[1]

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Online videos provide a novel, and often interactive, platform for the popularization of science. One successful collection is hosted on the TED (Technology, Entertainment, Design) web site. This study uses a range of bibliometric (citation) and webometric (usage and bookmarking) indicators to examine TED videos in order to provide insights into the type and scope of their impact. The results suggest that TED Talks impact primarily on the public sphere, with about three quarters of a billion total views, rather than the academic realm. Differences were found among broad disciplinary areas, with art and design videos having generally lower levels of impact but science and technology videos generating otherwise average impact for TED. Many of the metrics were only loosely related, but there was a general consensus about the most popular videos as measured through views or comments on YouTube and the TED site. Moreover, most videos were found in at least one online syllabus and videos in online syllabi tended to be more viewed, discussed and blogged. Less liked videos generated more discussion, although this may be because they are more controversial. Science and technology videos presented by academics were more liked than those by non-academics, showing that academics are not disadvantaged in this new media environment.

INTRODUCTION

The popularization of science, that is, the wide dissemination of scientific information to a non-specialized public (Jensen, Rouquier, Kreimer, & Croissant, 2008), has traditionally been restricted to magazines, newspapers, public lectures, radio, and television (Bentley & Kyvik, 2011). However, the Internet is now "the main source of information for learning about specific scientific issues" and equals the television as a source for Americans to find general science and technology information (National Science Board, 2012, p.7-4). This shift can be understood in terms of the percentage of time spent on science and technology news online and on air: Science and technology news represent less than 5% of the time of major television broadcast networks in the U.S, yet has been demonstrated to occupy more than 10% of the most frequently linked-to blogs in a given week and nearly 40% of the Twitter content for a given week (National Science Board, 2012).

Probably as a result of the media used, early scholars of scientific communication have expressed concern over the uni-directionality of science communication; that is, the inability for the public to engage and publicly discuss the disseminated information (e.g., Kidd, 1988). This has changed dramatically due to the social web, as predicted by Weigold (2001, p. 169), who anticipated that the Web would "dramatically change the relationships of the players in science communication" by combining "the information richness of print with the demonstration power of broadcast in a seamless, accessible, interactive fashion."

Online videos are one instantiation of a Web-based genre that provides a platform for interactivity. Professionally-generated and user-generated online videos have surged in popularity in recent years.

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YouTube, a website launched in 2005 for sharing video content, is the third most visited website in the world, after Google and Facebook (Alexa, 2012) and contains a wealth of scientific and educational videos. Promises of interactivity have been realized: A recent study of YouTube found its Science & Technology category to be prominent amongst a collection of highly discussed videos (Thelwall, Sud, & Vis, 2012).

Although a number of scientific, educational and governmental institutions have created YouTube channels and other video-based popularization efforts (e.g., Haran & Poliakoff, 2012), few seem to have garnered the notoriety of TED Talks. TED began in 1984 as a conference that brought together scholars, artists, and innovators from Technology, Entertainment, and Design (TED). The non-profit currently hosts two annual conferences as well as a video site, blog, newsletter, Twitter feed, translation project, fellowship program, local programming initiative, campaign to raise standards in advertising, and an annual $100,000 prize (TED, 2012). The mission of TED is one of change and engagement:

> We believe passionately in the power of ideas to change attitudes, lives and ultimately, the world. So we're building here a clearinghouse that offers free knowledge and inspiration from the world's most inspired thinkers, and also a community of curious souls to engage with ideas and each other. (TED, 2012)

The primary event of TED is the conference, a four-day spectacle with 50 speakers, including politicians, entrepreneurs, Nobel Prize winners, and performers who are each asked to present their work in 18 minutes or less. TED presenters are given access to state-of-the-art staging, lighting, and visual displays to entertain their audience. Although the conference has been criticized for elitism due to exclusive and expensive conference admittance (Lacy, 2008; 2010), TED provides free access to a select group of videos (TED Talks) through the TED web site. Under a creative commons license, these videos are made available on YouTube, Netflix instant streaming, iTunes and are promoted through various tools such as Facebook, Twitter, TED Radio Hour, and an RSS feed. Translations and transcriptions of the videos are available in 88 languages, with an additional 21 languages in process (TED, 2012).

Each day, more than half a million viewers seem to access TED Talks (TED, 2012). This is perhaps not surprising given that more than 90% of Americans claim to be at last moderately interested in Science and Technology (S&T) news and 13% claim to follow S&T news "very closely" (National Science Board, 2012; see also Pew, 2009). However, there has to-date been no systematic public evaluation of the impact of TED videos or, in the words of the TED mission statement, the degree to which the videos *change* or *engage* the users who access the content. One way to measure impact and engagement is through quantitative online traces of user interaction. Formal bibliometric measures, such as citations in books, journals, and syllabi provide an understanding of how academics and educators are engaging with the material. Webometric traces such as views, comments on the videos, user likes/dislikes, and presence in blogs may also demonstrate use by a wider public.

The overarching goal of this project is to provide a macro level analysis of the impact of TED Talks using a range of different impact metrics and focusing on the value of TED for different broad disciplinary areas, the role of academic and non-academic presenters and the ability of talks to provoke discussion. Analysis of the different sources of impact can provide an initial understanding of the types of use and, by extension, the type of users of this material. Compelling arguments have been made for popularizing science: "our political and economic well being are dependent on a citizenry that can participate intelligently in the making of crucial public policy decisions when an ever increasing proportion of such decisions have a scientific or technical aspect" (Kidd, 1988, p.

127). Given the apparently huge audience for TED Talks, these videos present an opportunity for the widespread popularization of science. It is therefore necessary to investigate the degree to which these videos are having an impact in the public and scholarly spheres. In particular, this project investigates the following research questions.

1. Do the apparent levels of impact of TED Talks vary substantially according to the metric used?
2. Are there broad disciplinary differences in the values of the different metrics?
3. Do the different metrics assess similar aspects of the TED videos?
4. Does the popularity of a video affect the extent to which it is discussed?
5. Do academic presenters elicit a different reaction from that of non-academic presenters for scientific talks?

LITERATURE REVIEW

Popularization of science

Much of the literature on science communication focuses on the role of science journalists and science information professionals (i.e., spokespeople for scientific societies, major research laboratories, etc.) in the popularization of science (see Weigold [2001] for a review). Numerous studies have demonstrated the low-level of formal science education possessed by these journalists and, perhaps as a result, the dissatisfaction of scientists with the press coverage of science (e.g., Weigold, 2001; Petersen, Anderson, Allan, & Wilkinson, 2009). However, recent studies point to the emergence of more collaborative relationships (Peters et al., 2012) and changes in medialization (i.e., mass media coverage of science): increasing representation of science in the mass media, increasingly levels of controversy in coverage, and increasing diversity of actors and content (Tøsse, 2012).

One important actor in the popularization of science is the scientist (Bentley & Kyvik, 2011). There is a belief that “scientists have a basic responsibility to interact with the public” (Weigold, 2001, p. 173). However, there is a “widespread perception that scientists are not effective communicators, at least when the audience is the general public” (Weigold, 2001, p. 172). A number of rationales have been provided for this including the highly technical language of scientific communication (Weigold, 2001), the qualified way in which scientists present their results (Weigold, 2001), the lack of training in communicating to non-scientists (Dunwoody & Ryan, 1985), and the lack of adequate rewards for engaging in this activity (Dunwoody & Ryan, 1985). There is also the suggestion that popularization should be secondary to scientific publishing (Bentley & Kyvik, 2011; Jensen, Rouquier, Kreimer, & Croissant, 2008) and that engaging in such activity may undermine an academic’s reputation among peers (Weigold, 2001).

Nevertheless, this sentiment has been largely dispelled by the finding that popularization is largely conducted by the scientific “elite” (Jensen et al., 2008); that is, senior, prolific, and highly cited academics tend to be most likely to engage in popularization activities (Bentley & Kyvik, 2011; Jensen et al., 2008; Dunwoody, Brossard, & Dudo, 2009; Kyvik, 2005). Arguments for popularization echo those of the National Science Board (2012): “it is increasingly difficult for Americans to be competent workers, consumers, and citizens without some degree of competency in S&T” (p. 7-6). Scientists have been charged with enabling citizens to achieve this competency by engaging in popularization (Jensen et al., 2008), particularly when they are receiving governmental funding for their research (Tsfati, Cohen, & Gunther, 2011). Studies examining the degree to which scholars engage in popularization have demonstrated that scholars are primarily motivated by intrinsic rewards (Dunwoody, Brossard, & Dudo, 2009) and that the degree to which scholars engage in popularization varies significantly by discipline, with life scientists doing the least amount (Jensen, Rouquier, Kreimer, & Croissant, 2008). However, there have been a limited number of studies to examine the impact and nature of these popularization efforts, particularly with the potential for interactivity offered with online genres.

Online videos

Early, predominately user-generated, YouTube videos set the tone and format that would dominate the genre of online videos: "short, mostly humorous and easily accessible" (Kim, 2012). The professionally-generated and scientific content that followed mimicked these genre conventions. One group of professionals using this medium are journalists: The mainstream media is witnessing a greater use of and interaction with online videos with journalists producing online videos (May, 2010) and incorporating user-generated videos into their reporting (Lee, 2012). The media shift is not without consequences to the content and standards—research has shown that deviations from traditional journalistic practices are standard in online videos and better received by audiences (Peer & Ksiazek, 2011).

The ability to reach a large public audience has drawn governmental and health agencies to online videos (Thackeray, Neiger, Smith, & Wagenen, 2012). Particularly suitable for this format are public service announcements (PSAs), which have been demonstrated to have a high degree of persuasiveness for their online audiences (Backinger, Pilsner, Augustson, Frydl, & Rowden, 2012; Paek, Hove, Jeong, & Kim, 2011). However, the public creation of health-related videos has led to some concerns about the "risk of unverified medical videos" and the appropriateness of public trust in online videos (see Thelwall, Kousha, Weller & Puschmann (in press) for related literature). Despite these concerns, recent surveys show a growing scepticism in information found online (National Science Board, 2012).

The pedagogical value of online videos has been explored across disciplinary domains (e.g., Jaffar, 2012; Burke & Snyder, 2008; Desmet, 2009; Trier, 2007; Juhasz, 2009; Berk, 2009, Jones & Cuthrell, 2011; Clifton & Mann, 2011; Knösel, Jung, & Bleckmann, 2011), with varying levels of success and enthusiasm. Surveys of the use of YouTube by academics have varied—one study found that 42% of health educators in a single university used YouTube (Burke, Snyder, & Rager, 2009); a similar study of a German university found that less than 10% claimed to have used this platform for teaching (Weller, Dornstädter, Freimanis, Klein, & Perez, 2010). To facilitate the use of online videos for educational purposes, many governmental and educational institutions have designated YouTube "channels" for educational material (Jaffar, 2012; Thelwall, Kousha, Weller & Puschmann, in press; Cooper et al., 2010; Thackeray, Neiger, Smith, & Van Wagenen, 2012; Fernandez et al., 2011; Young, 2008).

Evidence of adoption of online videos by the scholarly community is not as strong, with a few notable exceptions: the *Journal of Visualized Experiments* publishes videos of scientific experiments; YouTube summaries are provided for articles in *The Journal of Number Theory*; and *Nature* provides select video interviews with authors and editors via a designated YouTube channel (Thelwall, Kousha, Weller & Puschmann, in press). Despite these initiatives, citations to web formats of any kind remain scarce—a 2010 study demonstrated that only 0.3% of articles of U.K. scholars included a web citation (Creaser, Oppenheim, & Summers, 2011). Studies of citations to online videos have shown similarly low, yet increasing, numbers of citations (Kousha, Thelwall, & Abdoli [in press]). However, it has been suggested that the lack of references to web 2.0 formats may be a result not of lack of use, but rather lack of citation standards for these formats (Gray, Thompson, Clerehan, Sheard, & Hamilton, 2008).

Proponents of online videos suggest that they may provide a more accessible format for disseminating information about science to the lay public (Thelwall, Kousha, Weller & Puschmann, in press; Young, 2011b). It certainly provides a platform where professors can become superstars, as their videos are viewed by millions of people across the world (Young, 2008; Young, 2011a). As Young (2008) noted, “Web video opens a new form of public intellectualism to scholars looking to participate in an increasingly visual culture” (para. 2). This may feed into new forms of academic capital—similarly to citations, downloads and other visible traces of online interaction can function as attention metrics. Studies have shown that productivity in online platforms is largely dependent on metrics of attention - people are more likely to continue creating online material when that material receives positive attention, such as downloads, views, or commentary (Huberman, Romero, & Wu, 2009). In academia, where an economy of attention prevails, positive and immediate online affirmation may incentivize scholars to engage in this environment. However, there have been few studies to examine the relationship between traditional measures of academic impact and the production of online videos.

METHODS

Selection and organization of videos

The first task was to compile a list of TED Talks for analysis. Multiple lists of TED Talks exist: The TED website organizes TED Talks into lists of (non-exclusive) categories, making a compilation from the website difficult. The official YouTube channel, TEDTalks by the user TEDtalksDirector, provides a list of the videos available on this platform, but this is not comprehensive. A TED-endorsed list, provided in spreadsheet format, is provided on the official TED blog: http://blog.ted.com/2010/06/17/audio_podcasts/. This was used as the primary source; however, it is also not comprehensive and was augmented by titles from the other lists when gaps were identified.

The spreadsheet provided by TED listed the talk titles with presenter names included (e.g., “Aditi Shakardass: A second opinion on learning disorders”). However, it seems unlikely that the author name would always be included in the title in a standard citation. Therefore, to improve querying, each of these titles was converted into a short title followed by the last name of the presenter. For example, the title above was converted into a more basic query: "A second opinion on learning disorders" Shankardass. In addition, differences existed between titles in the spreadsheet, titles associated with the videos on the TED website and the titles of the videos in the official TEDTalks YouTube channel. These were noticed in approximately one-third of talks. For example, two titles used for the same talk were "Michael Pritchard makes filthy water drinkable" and "Michael Pritchard's water filter turns filthy water drinkable", but larger variations for the same talk were also identified, such as "Bonnie Bassler: The secret social lives of bacteria" and "Bonnie Bassler on how bacteria talk". To ensure that all impact measures for a given video were aggregated, we used all title variants and combined the results.

Measurements of impact

TED metrics. The TED web site was crawled by the research crawler SocSciBot (http://socscibot.wlv.ac.uk) obeying the robots.txt convention for ethical crawling. A second program was written to identify pages from the crawl that hosted videos. From each video hosting page the video name was extracted by the second program as well as the number of views of the video and the number of comments on it, the date that the video was posted to the TED site, any tags applied to the video and any themes to which it was classified (e.g., Rethinking Poverty, Women Reshaping the World). Duplicate videos were discarded, i.e., those with identical titles to other videos in the site.

YouTube metrics. Each video was searched for in YouTube using the short search strings via the YouTube Applications Programming Interface (API) in Webometric Analyst. Most queries returned multiple matches – often copies of the same video uploaded by different people. All videos except those from the official TED YouTube channel TEDTalks were removed. These videos were then manually matched against the master list of TED Talks. In many cases the names were different across the two sources and not all videos were found in the TEDTalks channel. In cases of unmatched videos, different queries were tried and alternative TED-related channels were checked, resulting in the identification of a few extra non-TEDTalks videos. For each matched video a range of statistics was extracted from the YouTube API, including the number of views, comments, positive ratings and negative ratings and the number of times it had been Favorited.

Google Scholar citations. TED Talks were searched manually using the short search strings composed from TED Talk titles, including multiple searches for those videos with alternate titles. Results were manually assessed to determine whether they represented a record for the TED Talk video or for another scholarly genre. For example, when searching for Schwartz's "The paradox of choice", GoogleScholar returns a record for Schwartz's book of the same name (with more than 1400 citations). In order to validate the identity of the cited genre, it was sometimes necessary to access the citing articles and examine the references in full. The "cited by" number for such records was then manually compiled. In cases where multiple accurate records existed, the "cited by" numbers were summed.

Web of Science citations. Using the Cited Reference Search function in the Web of Knowledge (WoK), we searched for references to TED Talks from articles indexed by Thomson Reuters. The query was generated by testing the most highly cited videos from the Google Scholar search by author and identifying all possible ways in which the cited work field was coded. Since there were multiple manifestations (e.g., ted, tedtalk*, TED Talk), the most inclusive search string was chosen for searching: ted*. This yielded 706 results. These results were individually examined to see (a) whether they were a TED Talk and (b) if they were associated with a presenter in our dataset. If the presenter had only given one talk, the citation was assumed to match this talk. However, in the case of multiple presentations, we had to identify which talk matched the citation. In many cases, this involved manually scanning the citing article for the reference. Dates and authors alone were not sufficient as authors did not cite in standard ways (e.g., one might provide the date of access rather than the date of publication). All identified citations were totalled.

Mendeley references. Using the short search strings, the TED Talks were searched automatically in Mendeley via Webometric Analyst to identify and count valid Mendeley references (i.e., the number of users that had added the talks to their profile). All references were manually checked for false matches.

Google Books results. Using the short search strings, the TED Talks were searched manually in Google Books to identify and count valid book citations. Automatic searches were first tried using the Google Book Search API but this gave incorrect matches when there were zero correct matches and so could not be used. At the time of use the Google Book search interface mixed correct and partial matches in its search results, but if the order of the results was changed to "Sorted by date" then all the incorrect matches were removed. This apparently undocumented feature of Google Books was used. In other words, each title was searched for in Google Books, then "Sorted by date" was clicked on and the number of results was returned. Although the Google Books API had a similar feature "orderBy=newest", this was not used because it did not remove false matches.

Syllabi. Using the short search strings, the TED Talks were searched automatically in Bing via its API connected to by Webometric Analyst to identify citations to them in online syllabi. Using a modification of a previously used technique (Kousha & Thelwall, 2008) each TED string was augmented with (a) the term syllabus and (b) the phrase "reading list" and then the two queries were submitted to Bing and the results (lists of matching URLs) were combined. To avoid multiple results from similar pages in the same site, the number of matching domain names was counted rather than the number of matching URLs. The snippets in the results were manually checked for valid matches and a judgement made in cases where the context was unclear. Examination of the results revealed too many false matches for the phrase "reading list" and so the queries were repeated with the term syllabus alone. The queries still returned a high proportion of false matches and so the keyword “TED” was also added. This gave a reasonable level of matching, and the final results were manually checked to remove false matches. The checking counted a web page as a match if the TED video was listed in an online syllabus or course reading list or if it was mentioned in the context of a teaching or training experience. For instance, if a student-created web page mentioned the syllabus of a course and that the student had watched the video for their course, then this was counted as a valid match.

Other document types. The procedure used to locate instances on syllabi was repeated but without the extra search terms *TED* and *syllabus* and with the advanced extra search terms (a) filetype:pdf and (b) filetype:doc added to identify matching online documents and with filetype:ppt to identify matching online PowerPoint presentations.

Video categories

In order to build coherent sets of videos within broad disciplinary areas, the top 10 TED-assigned tags were examined for disciplinary relevance. Of these tags, only four (science, technology, arts and design) seemed to be applied to videos in a way that was consistent with a broad disciplinary category. The other tags were: global issues, politics, education, entertainment, business and culture. The education tag was rejected because it was sometimes applied to videos about education and sometimes to educational videos, the politics tag was typically applied to political issues rather than videos focusing on politics, and the business tag was often applied to talks with a commercial angle rather than talks about business. The four selected tags were then merged into two broad disciplinary areas: Art & Design (194 videos) and Science & Technology (405 videos), with the remaining videos falling into an Other category (440 videos). Videos tagged with both Art & Design and Science & Technology were removed (164 videos).

The presenters of videos within the Science & Technology category were allocated into one of two groups: academics and non-academics. Academics were classed as people affiliated with a university or other academic institution that was involved in some way in education. This excluded a small number of those working at non-teaching research institutes and researchers working for government departments or industry. The classification decision was made by the authors with the aid of an additional coder.

Data cleaning

Preliminary tests were conducted on the data in an attempt to ensure that the main statistical comparisons would be unbiased. The main concern was that the TED videos gathered were published on the TED web sites between 2006 and 2012 but most of the statistics gathered about the videos are time-dependant. For example, it would be almost impossible for a video published in 2012 to have been cited in a book due to normal publication delays. Whilst all the citation-type statistics seem likely to be higher in the older videos, the same is not necessarily true for video viewing or commenting statistics since the continuing growth of the web may mean that later videos have a larger potential audience when they are initially published. Any overall trends in the statistics gathered could have an impact on the comparison of video types for any types of videos not evenly spread by year (e.g., if science videos tended to be older than average). Chi-squared tests revealed that some of the top 10 video tags were not evenly spread by year and so the distribution of the statistics over the years was investigated to identify its likely impact. This revealed that the citation statistics showed particularly large values for 2006 and particularly small values for 2011 and 2012 whereas the other statistics did not exhibit a monotonic trend. Hence the 2006, 2011 and 2012 citation statistics were removed from the analysis of tags.

Analysis

For each research question, an appropriate statistic or statistical test was selected, as described below. Since the data is in almost all cases highly skewed, non-parametric tests were used to seek evidence of differences. Kruskal-Wallis and median tests were used to assess differences between three groups within a single metric and Mann-Whitney tests were used in the case of two groups, or to differentiate between pairs of groups in cases where tests of three different groups revealed significant differences. Spearman correlations were used to detect similarity between metrics for the third research question. Correlation tests do not prove that two metrics have similar or related underlying causes but a significant correlation is an appropriate indicator that two metrics *may* measure something similar to each other. In order to guard against false positives, Bonferroni corrections were applied in all cases in which multiple simultaneous tests were conducted.

RESULTS

Levels of impact

Table 1 reports the amount that the videos are used with the different methods. The total column shows the large differences in the amount the videos are used in different contexts. In answer to the first research question, the seven orders of magnitude difference between the standard metric for academic outputs, Web of Knowledge citations, and the primary use mechanism, views in the TED web site, shows that there are substantial differences between the values of the metrics. The differences confirm the intuitive importance of using non-standard metrics (i.e., not based exclusively on academic citations) to evaluate the wider impact of these videos.

Table 1. Basic statistics about the various methods of use or interaction with the TED videos. The table is ordered by the total column.

Metric	Minimum	Median	Mean	Maximum	Total	Valid
TED web site views	44,441	338,969	517,437	9,946,996	620,406,446	1,199
YouTube views	462	43,311	99,184	3,991,983	111,681,275	1,126
Blog citations (Google blog search estimates)	0	3,120	9,073	441,000	10,905,376	1,202
YouTube Likes	2	485	900	26,591	1,013,231	1,126
YouTube Favorite count	3	299	767	38,139	863,458	1,126
YouTube comments	0	195	368	21,703	414,311	1,126
TED web site comments	8	117	187	5,921	224,629	1,199
YouTube Dislikes	0	34	69	1,456	78,053	1,126
Online mentions related to academic syllabi	0	1	2	50	2,070	1,202
Online mentions in PDF and Word documents	0	0	0	49	592	1,202
Google Scholar citations	0	0	0	75	505	1,202
Google Books citations	0	0	0	18	434	1,202
Mentions in PowerPoint presentations	0	0	0	238	392	1,202
Mendeley readers	0	0	0	30	231	1,202
Web of Knowledge citations	0	0	0	5	47	1,202
YouTube Like proportion	0.260	0.941	0.900	1.000	-	1,126

Disciplinary differences

A median test was used to see if each of the 13 statistics collected differed between Art & Design, Science & Technology and Others. This resulted in four metrics with significantly different medians between groups: YouTube comment counts, TED web site comment counts, syllabi mentions and YouTube like proportions (Table 2). Hence there is evidence of significant broad disciplinary differences for *some* of the video impact metrics.

Table 2. Tests for different medians between the Art & Design, Science & Technology and Others groups of videos. The table is ordered as in Table 1 and excludes the secondary metrics not tested for.

Metric	**Art & Design median**	**Science & Technology median**	**Others median**	**Significance of median differences**
TED web site views	271587	325647	315559	0.221
YouTube views	32774	47060	43710.5	0.192
Blog citations	1810	2280	2300	0.035
YouTube comments	79	199	202.5	0.000000**
TED web site comments	63	112	133	0.000000**
Online mentions related to academic syllabi	0	1	1	0.001*
Online mentions in PDF and Word documents	0	0	0	0.009
Google Scholar citations	0	0	0	0.008
Google Books citations	0	0	0	0.009
Online mentions in PowerPoint presentations	0	0	0	0.772
Mendeley readers	0	0	0	0.459
Web of Knowledge citations	0	0	0	0.347
YouTube Like proportion	0.9108	0.946	0.9248	0.000000**

*Significant at p = 0.05, ** significant at p=0.001 after an n = 13 Bonferroni correction to modify the alpha value from 0.05 to 0.004, 0.01 to 0.0008 and 0.001 to 0.00008.

For the four data sets pairwise Mann-Whitney U-tests were used to identify which of the groups had a significantly different values than the others. A Bonferroni correction for n = 3 was used to correct the alpha value from 0.05 to 0.0167 for each individual metric, giving the following results.

- YouTube comments**:** Art & Design is lower than Others (p=0.000).
- TED web site comments**:** Art & Design is lower than Others (p=0.000); Science & Technology is lower than Others (p=0.005)
- Syllabus mentions: Art & Design is lower than Others (p=0.000).
- YouTube Like proportion**:** Art & Design is lower than Others and Science & Technology (p=0.000); Science & Technology is higher than Others (p=0.000).

Since many of the medians were zero, a follow-up test was used to assess whether there were differences between the metrics despite identical medians. A Kruskal Wallis test was used to compare the distributions to see whether one group had generally larger values than another, even if their medians were the same. The identical set of significant results suggests that the zero medians have not hidden significant differences between groups for any of the metrics. Nevertheless, the Art & Design group has the lowest value for all metrics except PowerPoint Presentations, suggesting that this group of videos generally has the lowest level of activity across the board. The rank sums for Science & Technology and for Others are generally similar, suggesting that Art & Design is unusual whereas Science & Technology attracts a typical reaction within TED.

Table 3. Tests for different *distributions* between the Art & Design, Science & Technology and Others groups of videos. The table is ordered as in Table 2.

Metric	**Art & Design rank sum**	**Science & Technology rank sum**	**Others rank sum**	**Significance of rank sum differences**
TED web site views	468.33	526.49	532.22	0.036
YouTube views	419.4	499.07	495.76	0.192
Blog citations	467.42	524.5	537.9	0.022
YouTube comments	338.94	513.31	517.77	0.000000**
TED web site comments	374.81	521.61	578.36	0.000000**
Online mentions related to academic syllabi	278.77	355.09	350.86	0.001*
Online mentions in PDF and Word documents	299.8	343.28	351.84	0.007
Google Scholar citations	327.26	354.01	329.78	0.009
Google Books citations	313.54	359.53	331.09	0.005
Online mentions in PowerPoint presentations	341.73	335.94	339.31	0.796
Mendeley readers	330.96	343.31	337.64	0.458
Web of Knowledge citations	332.61	342.05	338.01	0.337
YouTube Like proportion	428.13	544.53	448.13	0.000000**

*Significant at p = 0.05, ** significant at p=0.001 after an n = 13 Bonferroni correction to modify the alpha value from 0.05 to 0.004, 0.01 to 0.0008 and 0.001 to 0.00008.

Comparison of impact types: Correlations between metrics

The correlations in Table 4 suggest the extent to which the metrics measure the same aspect of the impact of the videos. The metrics most closely related to scholarly communication are WoK citations, Google Scholar citations, Mendeley bookmarks, Google Books citations and PDF and doc citations. These metrics exhibit only moderate positive correlations with each other. The correlation between Google Scholar citations and WoK citations seems to be very low, at 0.264, for two metrics that are considered theoretically very similar and that previous studies have found to correlate highly for journal articles (e.g., Kousha & Thelwall, 2007). The low correlations may be an artefact of the low numbers involved for the metrics allowing random factors to exhibit a greater influence over the results. The highest of the other scholarly communication correlations is 0.408, between Google Scholar and Google Books, and the remaining correlations are all below 0.315.

Table 4. Spearman correlations between the TED video metrics. Correlations over 0.4 are highlighted in bold. Rows and columns are arranged to group similar types of metric together. [see end of paper]

In contrast to the scholarly communication metrics, the YouTube metrics and TED site metrics mostly correlate highly between each other. With the exception of the YouTube Like proportion metric, the others have correlations from 0.540 to 0.902. The YouTube Like proportion, an indicator of the popularity of videos, has only moderate correlations with view counts (0.368 with YouTube views, 0.369 with TEDTalks site views) and an even lower correlation with the number of comments (0.064 with YouTube comment counts, 0.169 with TEDTalks site comment counts). Taken together, this suggests that the more liked videos are not necessarily the more discussed or viewed. This would be consistent with TED containing a proportion of popular but controversial videos.

The three remaining metrics are blog citations, syllabus citations and PowerPoint citations.

- Blog mentions have a correlation above 0.4 with syllabus mentions (0.437), YouTube views (0.496), YouTube comments (0.427), TED site views (0.610) and TED site comments (0.498). The amount of blogging about a TED video therefore correlates moderately with the amount that it is viewed and discussed.
- Syllabus mentions have a correlation above 0.4 with Blog mentions (0.437), TED site views (0.440) and TED site comments (0.405). Hence there is a moderate correlation between the amount that a TED video is viewed and the amount that it gets listed in academic syllabi. The correlation with blog mentions may be a result of student course-related blogging.
- PowerPoint citations have low correlations with the other metrics – all below 0.2 – perhaps because the vast majority of videos have no identified PowerPoint citations.

Video popularity and discussion

Table 5 reports descriptive statistics for the popularity and commenting proportion metrics and Table 6 reports correlations between two popularity metrics and the number of comments per view for videos. There is an order of magnitude difference between videos in the statistics in both YouTube and the TED site. Moreover, YouTube videos attract over ten times as many comments per view as TED videos – presumably indicating a higher threshold to join TED to comment on videos than to join YouTube. This might be explained by video viewers having previously joined YouTube for other reasons and hence not needing to register again.

Table 5. Descriptive statistics for popularity and commenting proportion metrics.

Descriptive Statistics	**Minimum**	**Mean**	**Maximum**
TED comments per view	0.000,039	0.000,436	0.006,001
YouTube comments per view	0	0.005,049	0.035,005
YouTube Favorites per view	0.001,316	0.007,483	0.022,360
YouTube Likes per view	0.001,235	0.011,631	0.043,983
YouTube Dislikes per view	0	0.001,451	0.023,370

The lack of a significant correlation between YouTube Favorites per view and comments per view suggests that video popularity in this sense is not related to the amount of discussion about a video. In contrast, the significant negative correlation between YouTube Like proportions and both types of comments per view suggests that the more controversial or disliked videos attract the most discussion.

Table 6. Spearman correlations between popularity and commenting proportion metrics.

	YouTube Favorites per view	TED comments per view	YouTube comments per view
YouTube Like proportion	0.370**	-0.179**	-0.361**
YouTube Favorites per view	1	0.009	0.050

** Significant at p=0.001 (Bonferroni corrected, n=5). Other figures not significant at p=0.05.

Academic and non-academic authors of science and technology talks
Table 7 reports a comparison between the videos of academics and of non-academics for all the key statistics. Overall, academics' videos tend to attract more mentions in PDF and word documents and to receive a higher proportion of Likes. There were no significant differences between the two types of authors for the five "per view" statistics in Table 5.

Table 7. A comparison of medians for science and technology videos authored by academics and non-academics.

Metric	**Academic**	**Non-academics**
TED web site views	327,904	321,320
YouTube views	49,660	45,414
Blog citations	2,340	2,246
YouTube comments	223	190
TED web site comments	111	112
Online mentions related to academic syllabi	1	1
Online mentions in PDF and Word documents (acad. higher)	0	0*
Google Scholar citations	0	0
Google Books citations	0	0
Online mentions in PowerPoint presentations	0	0
Mendeley readers	0	0
Web of Knowledge citations	0	0
YouTube Like proportion	0.9574	0.9271**

*The distributions are significantly different at p = 0.05; **Significantly different at p=0.001 after an n = 13 Bonferroni correction to modify the alpha value from 0.05 to 0.004, 0.01 to 0.0008 and 0.001 to 0.00008, using a Mann-Whitney U test.

Limitations
The statistics gathered seem to be reasonably accurate but it is possible that there are technical reasons why some are inflated – such as design or marketing decisions for the TED web site for video views. Nevertheless, the significant correlations between most of the statistics indicate that the figures at least are reasonably consistent. We have no reason to believe that the YouTube figures are inflated and it seems unlikely that there has been any systematic attempt to manipulate them on a large enough scale to influence the results. The blog count statistics seem to be the least reliable because of the existence of spam blogs and the need for manual checking of the results. Small errors may also have occurred in the citation statistics if many authors cited TED videos in non-standard ways that were not captured by our searches. We used several different methods to search for TED video citations in an attempt to minimize this and do not expect this issue to be significant. More important, perhaps, is that TED videos may have caused citations for books associated with some of the talks in ways that could not be identified. Some of the speakers were essentially giving talks about claims made in their recently-published books and some academics may have found out about the ideas from the talks but then read and cited the book rather than the talk. This seems likely to apply most often to social scientists and humanities scholars, where books are more common scholarly outputs. These findings are not new in the sense that sometimes scholars are known to find relevant research in non-scientific sources, such as magazines and other news media (Kiernan, 2003). Moreover, correlations between press coverage of articles and their subsequent citation counts suggest that it is not surprising for a journal article to be cited after the research that it was

based upon was discovered through a traditional media outlet (Phillips, Kanter, Bednarczyk, & Tastad, 1991; Willems, & Woudstra, 1993).

The reported significance of the results is influenced by the large number of metrics investigated, leading to Bonferroni corrections that turned significant results into non-significant results. Nevertheless, the sample size of over 1,000 in most cases offsets this by increasing the power of the tests.

In terms of disciplinary differences, the study was only able to assess two broad groups: Science & Technology and Art & Design. There did not seem to be a substantial number of videos that were clearly about social science or humanities and these seemed difficult to classify accurately due to the presence of professional rather than academic topics, such as politicians making points rather than discussing politics. The classification of the three groups relies upon the TED web site internal classification scheme. This seemed to be reasonable in these cases but may have some inconsistencies for our purposes. In particular, videos often had overlapping themes. As an example, the videos, "How creativity is being strangled by the law" (by lawyer Larry Lessig about the internet) and "Dan Pink on the surprising science of motivation" discuss themes that are primarily from the humanities and social sciences respectively, despite being classed as Science & Technology under our scheme.

DISCUSSION

Returning to the research questions, the levels of impact for TED Talks vary substantially according to the metric used (RQ1) by seven orders of magnitude between video views and academic citations. This suggests that TED Talks have a much greater impact on the public than within the scholarly community. The large number of views may provide evidence that TED Talks in particular, and online videos more generally, are highly useful platforms for science popularization.

Videos demonstrating high degrees of use by scholars for research were scarce; there were relatively few Google Scholar, Google Books, or WoK citations or mentions in Mendeley. However, a small number of videos demonstrated a high degree of use on a number of academic metrics. Hans Rosling's "Debunking third-world myths with the best stats you've ever seen" was the most cited in WoK and also had a number of Mendeley readers. Sir Ken Robinson's "Bring on the learning revolution", "Do schools kills creativity", and "Changing education paradigms" were cited, included on syllabi, and read in Mendeley. Larry Lessig's "How creativity is being strangled by the law" was also highly cited both in WoK and GoogleScholar. Jane McGonigal's "Gaming can make a better world" was highly cited in GoogleScholar and GoogleBooks.

There were a fair number of indicators of educational impact: Nearly all videos were found on at least one online syllabus and a number were mentioned in .pdf and .doc files (where they were largely student-composed and student-directed products). Therefore, while TED Talks may not be highly consumed by academics for research, they may be of value to the academic community as pedagogical material.

Evidence was found of broad disciplinary differences in the values of the different metrics (RQ2) with Art & Design videos generally attracting less attention than others. Surprisingly, Science & Technology videos were not unusual in the context of TED and their proliferation (about a third of all talks) suggests that they are core to the TED experience. This finding requires further analysis as the composition of the Other category (and the degree to which some of the Other videos could be reclassed as Science & Technology) is unknown.

Science & Technology received higher scores in one category: YouTube Like proportions. More than 70% of the Science & Technology videos were at or above a 9:1 like to dislike ratio. For example, David Gallo's "Underwater astonishments" attracted 4320 Likes and only 16 Dislikes (99.6% Likes). This provides evidence of the positive reception of Science & Technology videos, perhaps reinforcing both the public's desire for science and technology news (National Science Board, 2012) and the successful popularization of science through this medium.

The correlation tests used to compare the different metrics suggested that they tend to assess somewhat different aspects of the TED videos (RQ3). The strongest correlations were between YouTube views and comments and TED site views and comments. This demonstrates that the audiences using TED and YouTube to watch the talks do not differ dramatically in their selection of videos, although some variation can be seen when looking at rank order of the most frequently viewed videos on each site (Table 8).

Table 8. Most viewed videos on YouTube at the TED website

Most viewed via YouTube	**Most viewed via TED site**
Robbins: Why we do what we do, and how we can do it better	Robinson: Do schools kill creativity
Robinson: Do schools kill creativity	Taylor: My stroke of insight
Hawking: Asking big questions about the universe	Mistry: The thrilling potential of SixthSense technology
Suarez: A 12-year-old app developer	Jobs: How to live before you die
Taylor: My stroke of insight	Gallo: Underwater astonishments

The remaining metrics, though significant, correlated at a very low level, suggesting that the metrics measure different aspects of the impact of these videos. However, some videos rose to the top on a number of metrics. Sir Ken Robinson's "Do schools kill creativity", for example, was among the top 5 most viewed and commented in both TED and YouTube as well as garnering the most citations from Google Scholar and appearing most frequently in online syllabi.

There was clear evidence that less liked videos are relatively more frequently discussed (RQ4), which is probably due to controversial videos generating the most debate. This aligns with previous research on internet discussions, which found that negativity in comments drives discussion (Chmiel, Sienkiewicz, Thelwall, Paltoglou, Buckley, Kappas, & Hołyst, 2011) or associates with increased discussion, including in YouTube (Thelwall, Sud & Vis, 2012). The nature of these discussions, however, remains unknown and a fertile area for future research. It is notable that the most discussed were not necessarily the most watched. For example, Richard Dawkins "An atheist's call to arms" was the most discussed video on YouTube and the TED site, but ranked 23rd in views on YouTube and 46th in views on the TED site.

Finally, academic presenters attract less negative reactions than non-academic presenters of scientific talks and more inclusion in pdfs and Word documents (RQ5). Both of these are consistent with academics having more authority and generating more trust than non-academics (Brewer & Ley, 2012; Farnsworth & Lichter, 2011; National Science Board, 2012). Furthermore, this contradicts the "widespread perception that scientists are not effective communicators" (Weigold, 2001, p. 172). This may demonstrate that current academics are more capable of disseminating via this mechanism that previously imagined, at least in terms of those selected to give a TED Talk.

Additional research should be done on the individuals engaging in this behavior and the impact of participating in TED upon their careers. Previous research indicated that a scientific elite was primarily involved in the popularization of science: typically more senior members of the scientific community. However, this may be changing with research demonstrating similar levels of popularization activity by age (e.g., Jensen, Rouquier, Kreimer, & Croissant, 2008). An informal perusal of TED Talks reinforces the notion that popularization may no longer be the realm of the aged academic. Future research is needed to systematically investigate change in the relationship between age and popularization. In addition, more research is also needed on the non-academic actors, the nature of their expertise, and their motivation for engaging in popularization.

CONCLUSION AND FUTURE RESEARCH

Science documentaries have been called "a meeting place for the didactic and the scientific, the truthful and the elegant; yet it is precisely the awe-inspiring presence of accredited scientists or the overwhelming elegance of multi-media spectacles that obligate viewers to acknowledge its contents' stratified texture" (van Dijck, 2006, p.21). TED Talks provide such a multi-media spectacle for scientists and non-scientists to share science with the masses. Although there are other video science series, few seem to have as successfully harnessed the potential of a social web to engage and interact with an audience. Nevertheless, as Leon (2008, p.11-12) noted (citing Roqueplo, 1983): "popularizing discourse is not usually a mere *translation* of a scientific text into language that is easily accessible for the public at large, but is rather the creation of a new thing, with its own being, characteristics, and purposes." TED Talks represent a new and, from the over half a billion views in YouTube and on the TED site, a highly successful form of popularizing discourse. Given that about a third of the videos cover topics related to science and technology, the TED initiative seems to be one of the most prominent science popularization initiatives in history. The popularity of TED also suggests that it may be influential in the public perception of science. Moreover, unlike broadcast television (e.g., Horizon, Nova), TED's primarily dissemination channel (web site) is interactive through comments making it possible to identify the engagement with the videos and the extent to which they generate discussion. From this evidence, it seems that the more controversial topics, perhaps including disproportionately many Science & Technology talks given by non-academics, attract the most comments and debate. This suggests that TED Talks, despite their sometimes bombastic style, can provoke reactions and disagreement rather than being always passively accepted.

The ecosystem of scholarly communication is changing and becoming modally diverse. Given the broader impact mandates of publicly funded research and the demonstrated popularity of video sites such as TED (and other sites like dolectures.com and futureeverything.org), it seems worth taking advantage of the proliferation of diverse and relevant metrics online to investigate further the potential of video science communication. This should hence help scientists understand how to best disseminate research in this highly attractive medium.

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Table 4. Spearman correlations between the TED video metrics. Correlations over 0.4 are highlighted in bold. Rows and columns are arranged to group similar types of metric together.

	WoK	Google Scholar	Google Books	Mendeley	Power-Point	PDF and doc	Syllabi	Blogs	YouTube views	YouTube comments	TED site comments	TED site views	YouTube Like prop.
WoK	1	0.264**	0.186**	0.103	0.110	0.157**	0.174**	0.133*	0.099	0.062	0.089	0.112x	0.076
Google Scholar		1	**0.408****	0.198**	0.089	0.272**	0.270**	0.191**	0.202**	0.145**	0.194**	0.239**	0.132*
Google Books			1	0.231**	0.175**	0.315**	0.312**	0.276**	0.234**	0.150**	0.197**	0.252**	0.087
Mendeley				1	0.178**	0.215**	0.205**	0.160**	0.133*	0.081	0.139*	0.176**	0.102
PowerPoint					1	0.165**	0.160**	0.095	0.100	0.057	0.082	0.124x	0.035
PDF and doc						1	0.382**	0.230**	0.245**	0.196**	0.241**	0.276**	0.167**
Syllabi							1	**0.437****	0.353**	0.322**	**0.405****	**0.440****	0.162**
Blogs								1	**0.496****	**0.427****	**0.498****	**0.610****	0.255**
YouTube views									1	**0.681****	**0.540****	**0.724****	0.368**
YouTube comments										1	**0.728****	**0.560****	0.064
TED site comments											1	**0.683****	0.169**
TED site views												1	0.369**
YouTube Like prop.													1

X significant at p=0.05; * Significant at p=0.01; ** Significant at p=0.001 (Bonferroni corrected) n=78, Lower the 0.05 to 0.000,641, lower the 0.01 to 0.000,128, lower the 0.001 to 0.000,013.