Dissemination vs. Dialogue: An Analysis of Public Engagement in Science Online

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Master of Science, is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Abstract

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In 1985 the Bodmer Report was released, which discussed the need for scientists to more effectively communicate their research to the public. The report opined that there was an information deficit among the public, and were this deficit to be remedied, then there would be a greater interest in science among the public. For some time, this model of science communication was the model of choice. In 2000, the Science and Society Report was released by the House of Lords. This report denounced the Bodmer Report. It stated that its core assumption was false, that an increased public knowledge could not be certain to increase public interest. This new report called for engagement with the public and the creation of a dialogue. It suggested that the public should be involved in all aspects of scientific discussion, even in the discussion as to the direction science should take.

Since the Science in Society report, a multitude of papers have been published discussing this need for engagement. This opinion calls the Bodmer Report's approach condescending and unnecessary. While benefits of having two-way dialogues are often discussed, there has been criticism of this movement, pointing out there is a lack of agreed topologies of science engagement, and while most espouse the need for engagement, fewer discuss the defined direction it should take. There have also been suggestions that the public desire differing levels, or "modes" of engagement depending on the platform, and that older models of science communication are sometimes preferred.

Through a thematic analysis of popular "YouTube" videos and a discussion analysis of comment threads on various popular websites, it is shown that, even in this relatively new media platform, people still gravitate towards a one-way mode of engagement.

Chapter 1

Introduction

This introduction will seek to place this thesis within the wider context of research, and to explain the reasoning for carrying out this study. There will also be a brief outline of the thesis provided.

1.1 Context and Motivation

The importance of science communication has long been understood, and has been championed by several groups. The issue however, is how to most effectively communicate science. To do this, several models have arisen, each championing different strategies. In 1985 the Bodmer Report was released (Bodmer 1985). This report put forward what is now referred to as the “information deficit model”. The report noted that because the public were not engaging in science, political and economic decisions were being made in regards to science that these decisions were not truly understood by a public which did not possess scientific literacy. The suggestion that Bodmer put forward was that the onus was on scientists to educate the public, and that a more educated public would be a more informed public, and therefore a public that truly impacted how scientific policy was formed.

However, fifteen years later the Bodmer Report fell out of favour. It was found that pushing the information deficit model had not led to an increase in the literacy of the public. Certain social scientists, such as Brian Wynne, began to push forward the idea that the information deficit model was failing, and a different model based on mutual engagement was necessary (Wynne 1992). In 2000, based on testimony like this, the House of Lords released the Science in Society Report (Anon 2000). This report concluded that not only were the public not more interested in science, they were also losing trust in both science, and scientists. They pointed to the widespread distrust of GM foods and the distrust in companies such as Monsanto. The outcome of this report was a new model that pushes for a "two-way" dialogue. It suggests that the most important factor is communication between scientists and the public, and through that, a trust will build and the public will be able to engage with scientific policy in a meaningful way.

Since this report, several studies have promoted a move towards engagement (Sayer et al. 2014; Robinson et al. 2014; Grogan 2014; Retzbach & Maier 2014). However, the aim of this thesis aims to show that eliminating the deficit model entirely is neither necessary nor desired. The research will aim to show that a middle ground is likely the preferred position. Scientists must contain scientific knowledge and institutional authority as well as engagement in their interactions with the general public. As discussed by Sturgis and Allum (Sturgis & Allum 2004), while promoting communication via the information deficit model has not led to an increased public knowledge base, it is important to continue to try and educate as "trust is always mediated by knowledge of the institutional arrangements under which expertise is authorised" (Sturgis & Allum 2004X, citing Yearley 2000).

Furthermore, although the Science in Society report was published 15 years ago, the perspective from the field of Science Education still promotes strategies to increase the public's knowledge base and so, still promotes aspects of the deficit model. A report from the European Commission entitled "Science Education for Responsible Citizenship" points out that there is still an "unevenness" in the level of science literacy across the public. However, it also points out that the public still seek to learn new information and that a more scientifically literate public are more conscious regarding scientific issues in a political context. The report also discusses the importance of new strategies for informal learning and science communication, which are not exclusively based in strategies that would have been suggested by the science in society report, but rather, take an approach which blends the ideas of the Bodmer Report and the Science in Society Report (European Commission 2015).

This work will also attempt to show that, in agreement with Jensen and Buckley (Jensen & Buckley 2014), in an online context at least, the public are in favour of a much lower level of engagement, one in which a two-way dialogue is not the most important aspect, and that in an online context, the onus is on communicators to disseminate that information using one-way engagement strategies found to be appealing to the public.

Finally, this thesis will seek to support the works of Bik and Goldstein, and Fausto *et. Al.* (Bik & Goldstein 2013; Fausto et al. 2012) by showing the importance of science communication in online context, especially understand the typography of engagement mechanisms in an online context. The research will also seek to show that there is a lack of robust typographies that fully encompass the mechanisms of dialogue based in engagement online, an issue discussed by Rowe (Rowe 2005).

1.2 Outline of Thesis

In Chapter 2, an outline of the literature will be provided, to give context to the field, and to present the argument.

Chapter 3 will outline the methodology, providing the rationale for the research methods selected, and to discuss the method by which, this research will be provided.

The first results of this study (a thematic video analysis) will be presented in Chapter 4, along with a discussion of these results and how they pertain to the argument raised here and in the Literature Review

Chapter 5 will present the second set of results (a thematic discussion analysis) and will also discuss these results in context with the literature, and also in context with the results and analysis presented in Chapter 4.

Conclusions will be presented and briefly discussed in Chapter 6, along with a summation of the research carried out.

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Chapter 2

Literature Review

2.1 Introduction

The impact and importance of science communication is well known, and constantly espoused. The means by which it is promoted however, has change numerous times in recent years. In 1985 the Bodmer Report was published (Bodmer 1985) promoting the "information deficit model" which states that the public's lack of interest in science was mainly due to a lack of knowledge. If one were to increase the knowledge of the public, one would also increase the interest. This model fell out of favour as it was considered too simplistic and too condescending. Moreover, the assumption is not necessarily true. More knowledge may not create more interest.

A report released in 2000 by the House of Lords (Anon 2000) champions a different, now popular strategy of public engagement. The suggestion is that scientists must first engage with the public, to earn their attention before imparting information. An increasing amount of recent research suggests that there must be a discourse in science communication and that science communication must be "two-way."

This has led to an evolution in the literature on the topic. Initially the literature advocates the "one-way" public understanding of science (PUS) and from the mid-1990s the "two-way" Public Engagement in Science and Technology (PEST) was espoused.

This Literature Review will seek to show that the divide is not that simple. Instead of there being two 'camps' it is more accurate to see strategies of science communication as a continuum. On one end there is PUS and on the other PEST. The strategies of PUS are those that promote science literacy. Towards the middle are the downstream approaches to science communication that attempt to disseminate the information in an appealing, but, such as the use of narrative or analogy. These strategies, while important, require no input from the audience and are primarily "one-way". Finally, there are the upstream approaches, including public communication and public participation. This review will present the literature, to show that each of these approaches are important and have their place, and that one cannot be neglected in favour of the others. Moreover, this review will seek to show that the onus is on science communicators to anticipate the level of engagement sought by the public.

This thesis will show that in addition to these binaries existing as more of a continuum, content creators often do not remain in one part of the given continuum, using aspects of PUS in one instance, before following a PEST model in another. Moreover, it will be shown that no one strategy appears to be inherently superior to another in terms of popularity.

2.2 Science Literacy

Underpinning the whole idea of science communication is science literacy, though this idea is often overlooked in favour of engagement. Even if there is the fullest intent to engage with the audience, if there is a failure to impart scientific literacy to the general public then there is an overall failure in the communication, no matter how good the other aspects may be.

The definition of what constitutes scientific literacy is one that is contested and has been defined and redefined. A review by Laugksch (Laugksch 2000) discusses the various definitions by which different researchers have called a person "literate." This ranges from simple definitions, such as simply being tested as competent or adequate in a subject, to more complex ones such as being able to demonstrate "mastery of a body of knowledge". This review also points out that whether approaching from a sociological viewpoint or from an educational one, the definition of literacy often has different assumptions about the learner and their needs.

A comprehensive definition, and the one applied during this project is the one set out by the Programme for International Student Assessment (PISA) of 2015. The report states that scientific literacy is achieved through proficiencies in three different competencies. The three competencies are the ability to:

- Explain phenomena scientifically
- Evaluate and design scientific inquiry
- Interpret data and evidence scientifically.

However, in order to achieve these competencies, different knowledge sets are required. The three knowledge sets discussed in the report are:

- Content Knowledge
- Procedural Knowledge
- Epistemic Knowledge

As the report put it: The scientifically literate person uses all 3 types of knowledge to support performance in all 3 competencies.

In order to be competent at explaining scientific phenomena, content knowledge is required in their explanation, procedural knowledge in their historical derivation, and epistemic knowledge in knowing why these phenomena are scientifically justified.

To competently design scientific inquiry, procedural knowledge is needed to understand experimental technique, content knowledge to understand if a specific test is appropriate, and epistemic knowledge to justify that the results have the correct meaning.

Finally, to interpret data and evidence scientifically; content knowledge is needed to ensure the data fits with accepted scientific knowledge, procedural knowledge to ensure the data is viable, and epistemic knowledge to determine if it is justified.

Content Knowledge: Content Knowledge is in many ways the simplest to define, it is the ability to explain the scientific facts and principles. An example given by the report is: the ability to explain the nature and processes involved in photosynthesis. This knowledge base is likely the most relatable and easiest achieved by any science communicator, as it the basis upon which their media is based. However, this knowledge cannot be abandoned in favour of engagement strategies, as that renders any communication as engaging, but wholly ineffective.

Procedural Knowledge: Procedural Knowledge is the ability to relate how scientists obtained their results. It also encompasses the ability to design experiments, taking into account controls and elimination of variables. A person with good procedural knowledge would also know the value of repeating measurements in order to minimise error. It allows the student to offer hypotheses to explain physical phenomena, and then design experiments that would test these hypotheses. This knowledge also covers the representation of data, using graphs and tables.

Epistemic Knowledge: Possibly the hardest to define, epistemic knowledge is often referred to as the “nature of science”. This knowledge entails all that does not fit within the previous two knowledges. Therefore, it often appears nebulous and has been defined multiple ways, as discussed by Eduran *et al.* (Erduran & Dagher 2014). In this report, epistemic knowledge is called the “unifying strand” linking all aspects of science, and is also called “a particular way of thinking that is underpinned by certain values and beliefs inherent to scientific knowledge or the development of scientific knowledge”. It covers an understanding of the scientific method, and why science is conducted according to this method. This knowledge also covers the meaning of terms such as hypothesis and theory in a scientific context.

In the course of this study one aim will be to look for evidence of online content creators attempting to impart knowledge about these competencies to the viewer. This would therefore be an attempt to impart full scientific literacy to the viewer.

2.3 Dissemination Based Engagement

2.3.1 Evolution from PUS to PEST

This kind of engagement includes strategies that are designed to achieve the aims of the Bodmer Report. It uses ideas generated by the speaker to attempt to capture the interest of the listener, while still not actively engaging in a two-way dialogue with them. This would be described by Irwin (Bucchi et al. n.d.) as "first-order engagement" wherein a communicator is using various strategies to engage, but is expecting no feedback from the audience.

To say however, that PUS and PEST are a simple binary is historically inaccurate and practically unhelpful. There was a gradual evolution from one to the other, putting them at either end of a spectrum. The PUS "information deficit" model was exemplified by work such as Durant's Public Understanding of Science (Durant 1989) wherein the benefits of having a more scientifically literate public, and the methods that would best bridge the perceived deficit.

However, even at this point flaws were being noted in this viewpoint. Hillgartner, writing in 1990, suggests that while scientist's "popularising" science, i.e. simplifying it for public consumption, is a useful tool, scientists must still be careful. It is postulated that from a practical viewpoint, that knowledge may be distorted, and that perceiving communication as “appropriate simplification”, could easily be seen as condescending.

By 1999, movement away from the PUS model had begun, as Gaskell et al had noted that an increase in knowledge does not necessarily increase passion or support for science. Moreover, in 2000, in Chapter 5 of the book Between Understanding and Trust: The Public, Science and Technology, Durant, Bauer et al, discuss the flaws of the information deficit model and call for a framework that is more understanding of the publics’ needs, a framework that reflects that not all people are wholly ignorant of science, and takes engagement and culture into account (Durant, Bauer 2000).

By 2005, PEST has become a much more dominant research framework, with Gaskell, Einsiedel et al discussing how, in the surveys they conducted, the public seemed to want a greater role in determining science and to be in the “driver’s seat” as they put it. They warn that if this is not done, and the public not engaged with, large sections could then be alienated.

In 2009, even the rigid frameworks proposed in 2000 were being criticised. Bubela et al suggest that if proposed frameworks remain too rigid and one-sided, that meaningful engagement will never occur, as the language and engagement required for one group may not suit another.

2.3.2 Emphasis on representations of scientific content

The factors described in this section are the ones eventually coded for in this study. Here, they will be discussed in a general sense, and will be defined more accurately for coding purposes in a later section.

Visualisation: A paper by Gough *et al.* (Gough et al. 2014) examines the usefulness of artistry as a novel way to promote ideas, using visual and other media to convey things that words alone may be unable to. The implication of the article is that scientists would be unable to communicate any problems or research unless they themselves can visualise the issues at hand. The article also discusses how visualising a problem, either through words, images or videos can be extremely useful as a tool to convey scientific ideas. The importance of visualisation is also discussed by Robinson (Robinson et al. 2014) in which it is stated how valuable it can be when the public get out into nature to learn about natural phenomenon with scientists so that they can see and feel what it is they are learning about.

Relevance: Another study (Davies 2008) interviewed a collection of scientists to get their views on what constitutes best practices. Some ideas to come from this were vague and hard to analyse in a "YouTube" video, such as the idea that when talking about their research, scientists should avoid details and go purely for the "big picture". However, other ideas were much easier to analyse. The paper discusses the importance of relevance. It states that the speaker should almost immediately try to explain to the listener the importance of what is being said. The interviewees are also proponents of the use of humour in science communication. The importance of the effect relevance can have is discussed by Barua (Barua

2011) in the context of animal conservation. The author noted an incredible bias towards mammals and other animals deemed as cute. In Barua's estimation, this is due to the scientists' greater level of communication about these animals, giving them a much higher perceived significance and relevance.

Continuity: This study also notes that popular channels are ones that have continuity of style and of speaker. This may be popular as there is no need to become accustomed to a new speaker each video, who may possess an incompatible style.

Narrative: Avraamidou *et al.* (Avraamidou & Osborne 2009) supports the role of narrative in science communication, stating that students and the public are put off by science as it is "disconnected from their everyday experiences." Narrative devices however, are something familiar that we are exposed to from a very young age, so the usage of storytelling devices can prove to be very useful when dealing with science. Another paper, by van Dijck (van Dijck 2006) also discusses narrative modes, differentiating from the most common Expository mode ("this is what science is"), to the Speculative ("This is what could have happened"). Van Dijck points to the documentary show *Walking with Dinosaurs* as a show that encapsulates the speculative. This documentary often fills in blanks, showing physical characteristics or behaviours in dinosaurs that we cannot know occurred.

Transparency: Fausto (Fausto et al. 2012) discusses how on an online platform transparency of method can be extremely useful for communication. This involves communicating more than just the results of an experiment, but the me thods involved in generating the results. The suggestion is that it can connect research to the public on a more personal level, by informing the public what the individual scientists had to do to obtain the newsworthy research.

Humour: The use of humour as a strategy to communicate science has not been often discussed in the literature. One study by Pinto *et al* (Pinto et al. 2015). discusses the potential of humour as part of an evening of science "stand-up" that was organised by the researchers. They posited that, when humour is used correctly, it can establish a close relationship between scientists and the audience, despite the one-way "information-deficit" approach. Furthermore, it has the potential to make science more enjoyable due to the ubiquitous draw of comedy.

Another study by Riesch (Riesch 2015), takes a more critical approach of the use of humour in science communication. It is pointed out that, if applied incorrectly, it can appear elitist, as enjoyment is reliant on "getting the joke". However, the study does not discuss humour that, while discusses the content, does not rely on previous knowledge to find enjoyable. The study also notes that when applied correctly, humour has the ability to build a sense of community between scientists and the public.

Artistry: Several studies have discussed the potential impact that more artistic strategies may have on science communication. A review by Schwartz (Schwartz 2014) notes the ubiquitous nature of arts columns and arts pieces in newspapers and television programmes, despite the fact that the funding for science is consistently higher than the funding for arts. The suggestion that follows is to "go to where the audience are", suggesting that artistic approaches would have a much larger potential audience.

Another study by Drumm *et al* (Drumm et al. 2015) discusses the impact of a sculpture to demonstrate the principals involved in acoustics. The researchers note that not only does the project provide novel collaborations between scientists and artists, but states that this dissemination style form of science communication can trigger further forums, and further discussions, and may then start to incorporate new, dialogue based strategies.

Other authors state that the use of artistry in science communication can not only benefit the public, but scientists as well. A paper by Pollack and Korol (Pollack & Korol 2013) discusses the topic of using haikus to convey concepts in the area of neuroscience. They found that due to the constraints of the artistic form, the scientists had to find novel approaches to convey ideas in a manner that was both accessible and appealing.

Frequently in the research, these communication strategies are ignored in favour of the two way dialogues afforded by the PEST, two-way strategies. However, as discussed by Baram-Tsabari *et al.* (Baram-Tsabari & Osborne 2015) communicators should be wary of "reinventing the wheel" as the researchers put it. Though engagement strategies may not include a two-way model and belong to an older framework does not mean they lack necessity.

2.4 Dialogue Based Engagement

A wealth of recent work has been written on creating a dialogue between scientists and the public. The movement gained popularity following a Science in

Society Report in 2000 by the House of Lords (Anon 2000). In this report, the previous "information deficit model" was described as a "rather backward-looking vision" and even more damning, the British Council described it as "outmoded and potentially disastrous." This report followed a recommendation that the public was losing trust in science and the scientists who spoke on it. There have been many explanations put forward as to why this may be. Wynne argues that it may due to miscommunications of definitions (Wynne 2006). That both "science" and the models used to describe how to interact with public, are poorly defined, and the miscommunications leads to a lack of trust. Others such as Cacciatore, argue that the issue is one of authority, and that certain segments of society look to those other than scientists for guidance, such as Evangelical Christians referring to religious authority, leading to a mistrust of science (Cacciatore et al. 2016).

The example given was that of GM foods and the Monsanto Corporation. The report suggested that a lack of transparency on the part of the scientists was in part to blame for the distrust surrounding the issue. The recommendation was then put forward that a dialogue be created with the public, and that scientists be trained to do so. This two-way system could also be referred to as "second-order engagement" (Bucchi et al. n.d.).

Since then, numerous studies have been published espousing the need for a "two-way" system, and the forms such a system could take. The most obvious of these is to have scientists discussing aspects of science face-to-face, on a personal level, performing demonstrations for small groups of passers-by. One study (Sayer et al. 2014) is very supportive of this strategy, as they discuss the value of having stalls at open air events like festivals in order to interact with the public. This theme of a kind of science "Busking" involving scientists going to interact, as Sayer, Featherstone and Gosling put it, is a common theme in the literature. However, ideas such as these are largely inapplicable to online platforms, making two-way engagement a much more difficult prospect.

A paper by Robinson *et al.* (Robinson et al. 2014) discusses the importance of having scientists go out and actively engage with the public at a one-to-one level. Through a focus group, the researchers found that without this engagement, the public may have a lack of trust in science, and therefore doubt the truth. This was often due to a common question the public had: How could true integrity be maintained in the face of commercial interest. Moreover, for the scientist's benefit, those who did make the effort to engage with the public were often seen as brave, and breaking away from the "bunkers" of science. There is also a belief held by the researchers of this paper that by opening these discussions, scientists and the public can greatly impact the framing of the controversial climate change debate.

A consequence often feared by scientists attempting to engage with the public is that by discussing the uncertainty inherent in the scientific process, the public will begin to lose faith in science and in scientists. A study by Retzbach *et al.* (Retzbach & Maier 2014) looked at the effects of a focus group reading real world articles in the field of nanoscience. They found that when the articles discussed the uncertainty of science, it did not diminish their confidence in science. However, it was also found by the group that the articles presented did not change the views of science that they previously held.

A report by Grogan (Grogan 2014) however, goes somewhat against this idea in the area of synthetic biology while discussing engagement in focus groups.

Grogan espouses the need for "meaningful" engagement when discussing this area of research, stating that findings, and the uncertainty in these findings, must be framed very carefully. For example, when discussing risks and benefits, Grogan suggests that is it vital that it is the "potential" risks and benefits that are discussed and not absolutes. However, it is stated that once the framing has been achieved to a high standard, that the consequences of public engagement are very positive.

There are those who suggest that opening a dialogue with the public is not enough, that it must be the public who actively change and shape the direction of science communication. This is further discussed by Robinson *et al.* (Robinson et al. 2014) who set up events and workshops designed to hear how the public wish to inform science communication. The conclusions the author's reached were: A public concern that scientists would be able to retain integrity and impartiality when faced with the pressures of research funding and economic interests. Another issue, perhaps more relevant to this study is that although the public wish to be involved in the discussion on funding allocation, there is little knowledge of how such a discussion could take place. This theme, the often stated need for engagement with little knowledge as how to actively progress forward, is a common one within the literature studied.

This leads into the criticism that is faced by the PEST style of science communication. Some criticism is discussed in a report by Sturgis *et al.* (Sturgis & Allum 2004). This report begins by rightfully criticising aspects of the deficit model, pointing out that "to know science is to love it" is an assumption that cannot be ensured. The report pointed to surveys taken which showed that over time the public's knowledge of how science was conducted did not increase, despite the push in science communication under the deficit model. However, Sturgis warns against disregarding the deficit model entirely, stating that trust in something, like science is “always mediated by knowledge.” The comparison used in the paper is that of political science, pointing out that when an individual’s political knowledge is low, the impact of scandals is greatly overestimated, as may be the case in science. Sturgis notes that someone who may show a high level of science knowledge is more likely to be able to take that knowledge and place it into its correct context, and use that knowledge as the formation of their attitudes. The overall conclusion of the paper is that while the deficit model is simplistic and ill-fitting, it must not be thrown out entirely, but rather incorporated into a new framework.

There is also a growing movement in science communication which suggests that the simple definition of PEST as anything involving a “two-way dialogue” is not sufficient. That it lacks any solid objectives in its current form. As suggested by Rowe (Rowe 2005) PEST as a concept is poorly defined. That it has no solid, defined typology which needs to be determined. A stronger typology would allow for a greater translation of the ideas behind PEST into other media. For example, the paper discusses various modes of two-way interaction, from laymen simply participating, to the public deciding more strongly on how the material and the communication should unfold. The typology presented splits engagement into a number of different varieties. These range from very basic communication types, such as the traditional one-way broadcast to the public, to consultations with the public resulting in polls, or in asking the public to respond with their own thoughts, to full participation modes, such as open forums. While several of these are not applicable to a broadcast media, there are many examples that are, and have been folded into the qualitative analysis in a later section. However, the paper suggests that even a stronger typology would not be enough, that more fundamental ideas and objectives would need to be decided on. This criticism, that the direction of PEST is poorly defined, and without an adequate, agreed upon typology, is one is relevant frequently when reading literature on the subject.

This mode of thinking is relatively uncommon in this academic circle, with a possible reason for this suggested by Irwin *et al.* (Irwin et al. 2012). This article suggests that science communication as it stands is at an impasse. They suggest that PEST as a concept cannot grow and cannot evolve, likely due to the fact that the circle does not accept criticism. Criticism of any particular event is perceived as criticism of the idea as a whole. They argue that without the acceptance of constructive criticism, PEST as an idea will remain stagnant. Their argument is to make PEST a more recursive idea. To perhaps even perform science communication in a traditional manner under the PUS model, but being open to criticism, listening to the public and adjusting views accordingly.

There has also been discussion as to whether a move away from dissemination based strategies is necessarily wanted by the public. This is discussed by Jensen and Buckley (Jensen & Buckley 2014). In this paper, attendees of a science festival were surveyed to assess their views on science and science engagement. No evidence was found that the public seek to move away from dissemination based engagement, finding instead that perhaps mixtures of dissemination and dialogue based engagement strategies are the preferred way forward.

2.5 Social Media

As this thesis is about the modes of science communication used on "YouTube", an analysis of the research done in that field will be discussed.

An article by Bik and Goldstein (Bik & Goldstein 2013) attempts to provide an introduction to scientists, outlining the reasons to use online methods of engagement. They argue for the necessity of an online presence, suggesting that in an age in which most students and members of the public have an online presence, it is a detriment to the researcher to not have one themselves. This article also points out the instantaneous nature of having an online presence, where by sharing your work online one can immediately reach an audience. The other advantage of having an online presence is the size of the potential audience a scientist could reach. Websites like "Facebook" and Twitter have a higher monthly audience by orders of magnitude that even the most read popular science magazines.

The paper also points out that by having an online presence, scientists can instantly communicate with the public and any lay person can respond immediately. Moreover, in order to have a successful online presence, one must engage with the public to give them reason to back you. However, unlike other forms of media, the conversation here is completely fluid. The tone can be formal, or cordial, and can switch back and forth between the two.

However, the paper does discuss some downsides to online science communication. They point out that running a full blog is a very time intensive prospect, involving writing well thought out ideas. As well as this, to use a site such as Twitter can be difficult as its rapid fire can cause content to be buried quickly. The conclusion the papers reaches stresses the importance of uptake by scientists in online media.

A paper by Fausto *et al*. (Fausto et al. 2012) also discusses the need for science communication, pointing out that in the changing technological landscape we face, the metrics that scientists previously used to measure worth (citations, publications, etc.) may be incomplete and that an ability to communicate with the public must also be taken into consideration. This paper also shows that scientists who register with a particular blogging database (Research Blogging) also receive a higher number of citations, adding a corollary benefit to public engagement.

An article by Tan *et al*. (Tan 2013) discusses the benefits and drawbacks of using “YouTube” in the adjacent field of informal learning. Students were examined to see how they interacted with the site once told of its use by professors. A focus group was held with the students to hear their responses. It was found that the students found “YouTube” to be an incredibly helpful resource, actively seeking out videos relevant to the course. They also noted that there was an incentive to continue searching related materials, and further videos. Among some of the students, there was also an incentive to share material across different social networks, for example by posting the most interesting or relevant videos to “Facebook” or Twitter. The students also use simple metrics to identify the most pertinent or useful videos by looking at how well liked the video is or how positive the comments underneath are.

The video also raises some concerns that some students have about online media. They worry that, as anyone could conceivably produce content online, the veracity of the content produced may not be of a high standard. Some students also worry that information obtained in this rapid-fire format may not stick in the memory. Despite these reservations, the paper overwhelmingly shows student interest in using social media as a resource to learn in an informal setting, which may carry over to an even more causal communication space.

A 2004 article by Weigold (Weigold 2004) discussed how to attract teenagers to science based websites. Many aspects of this paper are now out of date. It discusses the common interactions teenagers have with the internet, but was published before the advent of "Facebook" and "YouTube", which are now hugely consumed. However, many of themes discussed in the paper are still relevant.

As part of the study the researchers held a focus group with the students in informal settings to attempt to learn what factors would increase their visitations to science web sites. There were two main results that are of relevance to this study. The first result was of relevance itself: The students interviewed did not see the point of visiting science websites (with NASA used as the example) because they did not understand why NASA were doing what they were doing. Paying more attention to relevance in science videos therefore may be a useful idea in improving its communication quality and its popularity.

The level of engagement that the teenagers wished to have was also discussed during the focus groups. Primarily, the group just wanted "cool stuff to see or do." This suggests that high levels of engagement, in which the public decide the nature of the communication is not the most preferred role, it suggests that a younger audience wish to sit back and be entertained. However, there is also call for a question and answer section, or a message board upon which the viewers own thoughts could be posted. This suggests that what this young audience want is to be heard. The primary wish may not be to dictate the nature or style of the communication delivered, but to have their voices heard by the creators of the content.

Song and Lee (Song & Lee 2014) suggest the importance of Web 2.0 in science communication and informal learning in their 2014 paper. Web 2.0 is an evolution of how the internet is used, with the focus moving toward user generated content and interactivity. This would allow learners to have greater control of the pace and content they choose to learn. Web 2.0 would also encourage them to create and disseminate content of their own. Social media is the most prominent form of Web 2.0. In their paper they outline the numerous possible forms that this new learning could take. Using previous research they created a number of criteria that would determine if an informal website utilised Web 2.0 features. These criteria included “harnessing the power of the crowd” which encourages users to bring and create their own content. Also included was determining whether the site actively tried to cultivate and interested ‘fanbase’.

The findings suggested a correlation between the use of Web 2.0 features and increased page views for those sites. However, as many other papers have stated, the researchers are unsure as to what forms this should take.

Some research has also been conducted on the interaction of scientists with other forms of social media. A paper by Haustein *et al*. takes quite a narrow look at how a single discipline of scientists (astrophysicists) engage on Twitter. They found that the most active users were also the ones that engaged the most, sending messages to other Twitter users and allowing themselves to be drawn into discussions about their own research and other scientific topics. However, a negative correlation was found between a scientist's Twitter activity and their publication rate, meaning the more active they were as communicators, the less prolific they were as scientists. While no correlation was found between citation number and Twitter impact the authors point out that this metric may not be particularly relevant as this disseminated research may still be able to impact a large amount of the general audience.

There was also an analysis of how students engage with "Facebook" in a classroom setting. A group of students were told they had the option of joining a "Facebook" group wherein they could discuss scientific issues related to the material they were discussing. The researchers found that while most joined the group, far fewer were willing to actively share and comment on what was being posted. The researchers concluded that while this was an effective, useful resource for the students, it would have been preferential for them to engage much more heavily with the idea. The paper also posited a reason that the engagement was so low: That in most online media, people, especially younger people have a much higher preference to "consume" media than they do in being responsible for that content's creation. This idea may have links back to the previously discussed idea that the public likes different "modes" of engagement, preferring different levels based on the event and media type that they are faced with.

2.6 “TED”

The “TED” (Technology, Entertainment and Design) talks platform is the most traditional form of science communication analysed in this project. It consists of a (normally) expert speaker, on stage communicating their ideas to a live audience. These talks are then uploaded to both the ted site, and to “YouTube”.

Some research has been done as to the interaction and nature of the ted talks. A paper by Tsou *et al.* (Tsou et al. 2014) looks at the nature of comments and discussion on ted talks in an attempt to see how people engage with ted and their feelings towards it. Comments were put through a discussion analysis on both ted’s website and “YouTube” to compare and contrast.

Several findings were noted. It was found that while 72.7 % of the comments analysed on ted were concerning the content of the talk, versus only 56.7 % of the comments on “YouTube”. However, commenters on “YouTube” were far more likely to engage in discussion with other commenters, though these interactions were often more negative and had a tendency to veer completely away from the topic at hand. The conclusion the researchers came to for these findings was that those going to ted were already invested in the site and its philosophy, whereas those on “YouTube” had stumbled upon these talks with less knowledge and therefore were more likely to be negative as they possessed no prior affection for the TED platform.

The findings of this paper may suggest that in order to reach the widest possible audience, “YouTube” would be a better platform in order to interact with the largest number of the general public. However, maintaining an open, productive discussion in this format may prove to be very difficult.

A paper by Sugimoto (Sugimoto & Thelwall 2013) discusses the reception these TED talks often receive. The findings of this paper suggest that the Art and Design related talks often receive less views than other ted talks such as the Science and Technology talks. The paper also found that in many cases, talks that received fewer likes often generated more discussion. However, this may have been simply due to the fact that these talks tended to be more controversial, creating debate and argument. Unfortunately, generating controversy is hardly a positive way to go about encouraging engagement in science.

The main idea coming through in review of all these engagement papers is that while all agree that engagement is beneficial, very few agree as to how. This may be due to how ill-defined the topology of engagement is, with few obvious frameworks to work by. However, it may be due to something else: perhaps the ideal situation is not one where the public decide the direction of all communication. Perhaps the public, when viewing online, enjoy and prefer science communication in a traditional format, but wish to feel heard by the communicators, while being shown simple, enjoyable science.

2.7 Conclusion

In conclusion, what the research seems to suggest is that dissemination models of science communication cannot be ignored, and should be considered as one-way engagement. As mentioned in the introduction, the European Commission's report on Science Education for Responsible Citizenship discusses that people are willing to learn to improve their knowledge base. Furthermore, they state their belief that an increased knowledge base will result in a more civilly conscious society. This reflects the views of Sturgis and Allum who hold that a public that trust in science is a public with increased knowledge as knowledge must be mediated by trust (Sturgis & Allum 2004). It also suggests that there is a place for at least some aspects of the information deficit model, as the public are seeking to learn, which means it may be predent to avoid "reinventing the wheel", as stated by Baram-Tsabari and Osborne (Baram-Tsabari & Osborne 2015). Meanwhile while there is a place for dialogue based engagement, in many cases the public may not require or desire it, and be content with dissemination based engagement. The public may be seeking a different order of engagement than would be preferred in face-to-face public strategies. This reflects the work of Jensen and Buckley (Jensen and Buckley 2014) which points out the importance of being aware of different levels of engagement. This thesis will seek to show that in the context of new media platforms, such as "YouTube", it is still dissemination based engagement strategies that thrive, perhaps with the incorporation of dialogue based strategies.

As will be shown in analysis of the videos and the dialogue, to reduce science communication to the simple binaries of PUS and PEST is crude and misleading. For one, the codes themselves are not mutually exclusive. Engaging in dissemination based modes in no way precludes the use of dialogue based modes, and vice versa. Therefore, even one single sample can use both modes.

Moreover, a single model to be preferentially used in all cases is neither practical nor advisable. Certain topics lend themselves to different models. For example, when discussing misconceptions of a scientific topic (as often done by Veristasium) it is useful to engage with people to understand which misconceptions are held and why. However, when the intention is simply to inform, there may not be any functional room for dialogue based engagement.

No singular model put forward can fully account for the complexities required to engage in truly meaningful communication, as in most cases, no model can be applied in isolation. Therefore, the models must be considered together, and as extreme ends of a spectrum. This thesis will also attempt to show that no singular point of this continuum holds an obvious superiority to any other point.

The gradual evolution of one form of communication to another, instead of the simple binary may account for why one model is neither superior, nor advisable. When engagement exists on a spectrum, there is no need to focus on a narrow portion of it. It is possible for all sections of the spectrum to possess merit.

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Chapter 3

Methodology

This section will cover all aspects of methodology. It will include the reasoning behind the selection of a qualitative research method, as well a definition of the research methods and terms used within this thesis. Furthermore, it will discuss how the source videos and discussions were selected. In the previous chapter, the reasoning behind the selection of codes and their place in the literature was discussed. Here, the focus will be on how those codes were applied while carrying out the research. For the discussion analysis, the selection process will be detailed as well as differences in methods between the video and discussion analysis. Links to videos will be provided as appendices.

3.1 Selection of Research Methods

Due to the nature of the project and the type of data, it was decided that the best way to complete this project and answer the research questions was to use qualitative research methods. As defined by Malterud (Malterud 2001), qualitative research is "the systematic collection, organisation, and interpretation of textual material derived from talk or observation." The material here to be collected, interpreted and analysed are, in the first section, a collection of "YouTube" videos, and in the second, discussions and message "threads" taken from a variety of online sources.

To be more specific, the form of qualitative research to be undertaken is a thematic analysis. Thematic Analysis is defined by Braun and Clarke (Braun & Clarke 2006) as "Thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data." These themes are gathered by identifying and relating codes. Codes are singular aspects of the source material that "appear interesting to the analyst." From the generation of these themes this project will attempt to understand the underlying causes of these themes as part of a "latent" thematic analysis. For example, in the first thematic analysis of the "YouTube" content, several codes such as Artistry (making use of original drawings or other artworks as done by minutephysics) and Humour (consistent attempts to make the audience laugh either through sarcasm or wit, such as that used by SciShow) may show a theme of prevalent dissemination based science communication. Furthermore, should this theme be strongly present, would that suggest there is an unwillingness to move to dialogue based approaches, and does that unwillingness come from the creators or the viewers?

Different approaches were used for the analysis of the videos and the analysis of the discussion threads. Both approaches are detailed by Hseih and Shannon (Hsieh & Shannon 2005). For the video analysis, the approach used is referred to as a "Directed Content Analysis." As stated by the researchers, this approach uses existing knowledge and theory with the purpose of building or expanding on that knowledge and theory. This approach involves using existing research and theory in order to provide you with an early coding framework. The example given by the paper is using the previous documented "five stages of grief" as codes to help understand the themes in discussing bereavement. In this, the coding is much more structured, with new codes only emerging when the existing framework is insufficient to explain something novel. While this approach allows existing theory to be easily expanded, it must be noted that by diving so deeply into the existing research, it can be easy to develop a strong personal bias. Any researcher undertaking this kind of research must be aware of this as they carry out their coding.

The Discussion Analysis was carried out using what Hseih and Shannon call a "Conventional Content Analysis." In this, as stated by the authors; "Researchers avoid using preconceived categories, instead allowing the categories and names for categories to flow from the data." Relevant theories or existing research can then be linked to the data once it has been organised and sorted into themes. This allows for researchers to remove a lot of their possible preconceived biases as the go into the study blind. However, it is possible to miss certain aspects of a code if a researcher fails to be consistent and thorough enough. By mixing both approaches in the undertaking of this research, it would be hoped to improve the standard and consistency of the research.

3.2 Thematic Video Analysis

The first portion of the study consisted of analysing the science communication on the various channels of "YouTube". This was done to see how many positive aspects of PUS that "YouTube" was able to encapsulate. This is done as a lead in to a study of engagement on “YouTube”. To answer the questions: For a new platform of media like the internet, where does it stand in the gamut of Dissemination to Dialogue based science communication? And is the public asking more for one or the other?

In order to study this, the criteria for selection of the videos had to be determined, as did the criteria by which to analyse these videos. These videos were then coded and analysed to see if any commonalties emerged.

In addition to this, the top science and technology ted talks were also analysed, to see how a more traditional form of scientific speaking compares to newer media designed for “YouTube”.

3.2.1 Selection Criteria of Videos

At first, it was decided to analyse 10 videos from the 7 most popular science channels on “YouTube”. The most popular channels were determined by subscriber count. This approach proved to be too wide a net and had to be further refined. Therefore, further criteria were introduced. The channel was excluded if it:

- Was not conducted in English (For example, the channel Manual do Mundo has 3.7 million subscribers, but is conducted in Portuguese, and could not be analysed)
- Contained mostly unrelated content (This eliminated the various channels that review new technology)

- Made no attempt to inform or communicate (For example, the Slo-Mo Guys present videos of various events filmed using a high speed camera, and while potentially interesting, there is no attempt made to explain what is occurring or why)
- Devoted itself to "Lifehack" style DIY.
- Was a spinoff of another media (National Geographic's videos for example, consist primarily of snippets of their television documentaries and does not use "YouTube" as its main platform, and was excluded for this reason)
- Was intended as an academic learning supplement, and therefore more in the confines of informal learning than science communication (such as Kahn Academy)

This gave a list of the popular informative channels on "YouTube". From there, the channel's most popular uploads were found. Before analysis, the number of subscribers per channels was noted (with the date), as were the view count on each video, date of uploading and length. These videos were then put aside to be analysed and coded based on selected criteria. As new criteria were added the videos were recoded to both incorporate the new criteria and to ensure the existing coding was self-consistent.

The selection of the ted talks had to be done according to a slightly different process. Due to the nature of ted many of their talks do not discuss science or technology at all. Therefore, the most popular relevant talks had to be determined before they could be analysed. To accomplish this, a list of the most popular science and technology talks was taken from the ted home website and these videos were used for analysis. For these videos both the view count from "YouTube" and from the ted website were noted.

3.2.2 Process of Analysis

The coding sheets to be used for analysis in this project were designed in Excel. The titles of the video were noted, as was the date of release, view count, and number of likes/dislikes that the video had accrued. At the beginning of the study, few codes were present. However, as more literature was analysed, more codes were added to the end of the sheet. As new codes were added, the videos were analysed again.

The videos were then viewed and criteria were filled in using a binary "Yes/No" metric. The reasoning for marking any particular video as Yes or as No is explained in the following section. A sample of the videos was also coded independently by two other researchers in order in to ensure that the findings were not the result of a personal bias.

3.2.3 Criteria of Analysis

Every one of the criteria chosen for analysis was sourced in literature as a measure of good science communication. To begin with, only 5 criteria were found, but as the analysis continued, more criteria were found and incorporated into the study. In the Literature Review the reasoning for the selection of these criteria was discussed. In this section, how they would be defined in the videos as positive or negative will be discussed.

3.2.3.1 Dissemination Strategies

Visualisation: A number of forms of visualisation were permitted as part of this project. A video was considered to make use of visualisation if any of the following were used as part of the video: If the video made use of props, images, artwork, or computer generated graphics to explain a concept. Metaphor and analogy were also considered to be devices to encourage visualisation in the viewer.

Relevance: Relevance is defined by Mirriam-Webster's dictionary as "practical and especially social applicability." The video was considered by the coder to include relevance if it made either: Reference to the science occurring in daily life (common technologies, everyday sightings or occurrences) or if the video discussed an important, newsworthy, wider issue (cancer, disease research, global warming etc.)

Continuity: Continuity of style was also considered as a factor for popular "YouTube" videos as it allows the reader to build an appreciation and loyalty for a specific channel or creator. For a video to be considered to employ continuity in their videos, the style of the video must be consistent with the other videos of that channel, and the speaker must be a regular presenter of that channel (the specific style and presenters of each channel are noted in the Results of the Thematic Analysis.)

Narrative: The role narrative can play in science communication is considered important as previously mentioned. However, narration can take many different forms, as discussed by Van Dijck (van Dijck 2006). Van Dijck discusses four primary modes of narration. Expository (What science is), Explanatory (how science works), Reconstructive (what happened), Speculative (what could have happened). As with Van Dijck, all modes are relevant and have their place. A video was decided to have used narrative devices if it made sustained use of any four of the narrative methods. Sustained use being defined as maintaining a constant discussion of the narrative without sudden segues between different subject matters or different narratives.

Transparency: Previously discussed was the importance of transparency of science in science communication. A video was considered to have made use of transparency if it not just discussed the science, but how the science was obtained, such as the motivation for the study or the experimental procedures used to generate the results obtained.

Humour: Though a relatively new area of discussion, the role of humour in science communication has been noted in the research. A video was considered to have made use of humour if (using the judgement of the coder) consistent attempts were made throughout the video to be humorous.

Artistry: The importance of artistic approaches, either using performing arts or the visual arts has been noted. If the video made use of original artworks of any kind, the coder was the mark it positively in this category.

3.2.3.2 Science Literacy

By analysing the following factors, it can be seen whether "YouTube"'s science communication does more than simply engage with the viewer, either through dissemination or dialogue. By analysing these variables, it can become apparent whether the video at the very least attempts to inform as well as engage. The modes for this type of literacy are taken from the 2015 PISA report, which details three modes, or "knowledges" of science literacy: Content, Procedural, and Epistemic (PISA 2015).

Content Knowledge: Content knowledge is an understanding of the process involved in scientific principles. Content knowledge is demonstrated for example by, demonstrating the reasoning and processes behind photosynthesis. A video was deemed to have attempted to inform content knowledge if, for the majority of the video, correct scientific information was explained to viewer.

Procedural Knowledge: Procedural Knowledge relates how scientists obtain their data, and how they design experiments to obtain these results. Procedural knowledge is also used in the generation of theories and hypotheses. A video that has discussed procedural knowledge if it discusses experiments used to obtain conclusions or results. It was also considered to have used procedural knowledge if it discusses how experiments are, in general, designed.

Epistemic Knowledge: As discussed by Erduran et al. (Erduran & Dagher 2014), epistemic knowledge is anything scientific not covered by content and procedural knowledges, and is often considered to be a discussion of the "nature of science." A video was said to have tried to convey epistemic knowledge if it discusses the scientific method (why science is done the way it is), or scientific definition of terms such as theory, or hypothesis.

3.2.3.3 Dialogue based Modes

This paper details various modes of engagement in an attempt to create a typology. It discusses modes and sub-modes of communication, of consultation and participation. Not all modes are applicable to “YouTube”, such as a focus group, which is participatory mode of science communication that is not feasible in this medium. Some videos may fit multiple modes, some may only fit one. The relevant ones are:

Communication 1 (broadcast): This form of communication is type that uses little to no engagement. It includes such forms as public meetings where one listens to a speaker. It also includes public information broadcasts and scientific television programmes or radio broadcasts. While most videos could be classified as primarily of this form, a video was tagged under this mode if it was purely a one-way communication i.e. if it made no attempt to elicit engagement from the viewer, or if it did not fall into any other of the dialogue based modes (Rowe 2005).

Communication 4 (hotline): This type of communication relies on public initiative. It relies on the public coming to the creators with a query or question. Several channels on “YouTube” often use a viewer’s question as a topic for a video. If the video makes an attempt to answer a viewer’s question as a video, or in part of a video it will be deemed to have made use of this type of communication (Rowe 2005).

Consultation 1 (opinion poll/survey): Possibly the first mode mentioned which sees interaction between creator and viewer. This mode allows the creator to ask the viewer for specific, often highly controlled information. Simultaneously, the viewer engages with their opinion. Often, opinions or questions posed by creators are done elsewhere, such as Twitter or “Facebook”, due to the more rapid nature of those platforms, and then the information gathered is used on “YouTube”. Therefore, if the video request, or has requested to obtain information for the video, that the public respond, either by specifically asking for the audience’s opinion, or to answer a posed question it is deemed to have used this mode (Rowe 2005).

Consultation 3 (content creation): In this mode, the viewer is asked for their own responses to the content presented to them. This mode allows for viewers to create their own content as a means of engaging with the creator of the video. This criterion is made if the viewer’s opinion on a scientific aspect of a video is asked for, through the comment section creating content of their own, such as their own videos (Rowe 2005).

Crowdsourcing (Gough et al. 2014) Crowdsourcing is when members of the public donate money towards the creation of content. This is usually done through websites such as “Kickstarter”, or ”Patreon”. This form of engagement allows for the viewers to be actively involved in the creation of the content they prefer, with most creators allowing “backers” to decide on the subject matter they wish to see discussed. If the videos were made, in part, due to public donations, then it was deemed to have made use of crowdsourcing.

3.3 Thematic Discussion Analysis.

While one part of this project looked at how a creator did (or did not) attempt to engage with viewers, the other looked at how internet users engaged with scientific content online. To examine this, a discussion analysis was performed on numerous different websites to examine differences in engagement online.

3.3.1 Selection of Discussions

The aim of the project is to select popular discussion from a cross section of the internet. Due to obtainable information, that metric had to be defined differently for each website used. The websites used were "YouTube", the "Facebook" page "I fucking love Science", and the subsection of Reddit.com known as r/science.

For "YouTube", the 5 most popular videos analysed in the thematic analysis had their "top" 30 comment threads analysed, with the "top comments" decided by selecting the "top comments" display function in each "YouTube" video (a thread being a single comment and all the replies nested to it).

"I fucking love science" has no facility by which to find the most popular "Facebook" posts of all time, therefore, for the purposes of this project a popular post was decided to be one that had generated more than 1000 comments, 5 of these posts had their comments sorted by selecting the "top comments" function built in to "Facebook", after which the top 30 comment threads were analysed

3.3.2 Coding Method

While for the thematic analysis, pre-determined codes were used to help analyse videos, for the discussion analysis, a reverse approach was taken. The comments were first analysed for common themes, ideas or statements, and these commonalities were grouped together in order to come up with a coherent coding scheme.

The process used to code these comments is similar to a method employed by Tsou *et al*. (Tsou et al. 2014) in their analysis of commenting behaviour on the ted talks platform, both on ted's main site and on "YouTube". As put by Hseih and Shannon (Hsieh & Shannon 2005) this coding approach is "open-ended." The codes are allowed to freely flow out of the data. All comments will be considered, be they about the content or the presenter, relevant or otherwise, or benign or inflammatory.

3.4 Conclusion

In this section, a brief definition of qualitative and thematic analysis was given, and the differences in approach (conventional vs. directed) was outlined and explained. The selection criteria for both the videos and the discussions were outlined and for the video analysis the practical application of the codes outlined in the Literature Review were discussed. In the following section (Chapter 4) the results of the Thematic Video Analysis will be discussed.

The methodology presented here will be sufficient to demonstrate that a variety of communication strategies are used in online science communication. These strategies range from "first-order", typically PUS style communication, to those creators who value and request engagement with their audiences.

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Chapter 4

Thematic Video Analysis

This section will deal with the results of the thematic video analysis and will discuss the significance that they hold in the world of science communication. The results will be presented and discussed as per the themes that they fit.

4.1 Channel Selection and Description

After applying the criteria set forward in Chapter 3, the selected channels and their subscriber count (as of 15/12/2015) are as follows:

Table 4.1: Channel titles and subscriber count.

Channel Name	**Subscriber count (millions)**
“VSauce”	9.687
“ASAPScience”	4.621
“TED”	4.105
“Smarter Every Day”	3.478
“Veritasium”	3.104
“MinutePhysics”	3.096
“SciShow”	2.904

“VSauce”: “VSauce” is a channel run by Michael Stevens, created in June of 2010. At 9.68 million subscribers as of 24/08/15, it is the most subscribed science communication channel on “YouTube”. The videos range from 5 minutes long to 12 minutes long and consist of Stevens talking to the camera, interspersed with images and videos designed to visualise the problems and concepts being discussed.

“ASAPScience”: “ASAPScience” is run by Mitchell Moffit and Gregory Brown. It was started in June 2012, and as of 24/08/15 has 4.12 million subscribers. Many of the videos discuss biology, as that is the area of expertise of the two presenters. The channels feature a top down view of a whiteboard with a voice-over. The whiteboard serves to illustrate the voiceover, not necessarily to visualise the science they discuss, but often just to accompany it.

“MinutePhysics”: “MinutePhysics” was started in June 2011 by Henry Reich. As the name may suggest, the videos are all quite short, between approximately 1 and 4 minutes. The style shares a lot of similarities with “ASAPScience”, featuring a top down view of drawings on paper and feature a voiceover by Reich. However, Reich’s videos focus more on physics and often feature more mathematically driven content.

“TED”: “TED” (Technology, Entertainment and Design) is conference series that began as a one off in 1984, becoming an annual event in 1990. The talks feature experts in their field discussing, as ted put it, “Ideas Worth Spreading”. The talks can range from anywhere between 5 and 20 minutes long, with the speaker presenting to a live audience. Since then the ted platform has expanded with the “TEDx” talks, which are independently organised conferences held under the ted banner. Though not all talks on the channel are related to science, many are, which has led them to be considered a prominent mode of science communication (Sugimoto & Thelwall 2013).

"Smarter Every Day": "Smarter Every Day" is run by Destin Sandlin, and began in its current form in 2011. Originally it began as a personal video blog, changing direction when success was had with some scientific content. The channel is filmed in the same style as a more "traditional" documentary, with Sandlin hosting and narrating the content. Often made use of, in Sandlin's videos, is a high speed camera, which is used to film at an incredibly high frame rate, effective showing the footage in slow motion. This allows viewers to visualise phenomena that would be too fast for the eye to detect.

Veritasium: Veritasium was founded in 2011 by Dr. Derek Muller. Veritasium is filmed in a similar manner to "Smarter Every Day", with a documentary format featuring Muller hosting or narrating. Hallmarks of Veritasium include interviews with the public in order to view and address common scientific misconceptions, and Veritasium's decision to create content at the highest filming quality possible, as discussed in his personal video "Quality vs. Quantity on YouTube".

"SciShow": "SciShow" was founded by Hank Green in 2012, as an "original channel" funded by "YouTube". The channel is primarily hosted by Green, with occasional episodes hosted by writer Michael Aranda. The videos discuss a variety of scientific topics, with Green hosting from in front of a green screen.

4.2 Dialogue Based Strategies

An interesting result of the thematic video analysis was the significant absence of dialogue based modes in the literature. Each video analysed had five codes that group together into theme of dialogue based engagement. As the analysis covers 70 videos, that's a total of 350 codes in total. Of these 350 codes for dialogue based engagement, only 81 codes were marked positively, meaning only 23 % of all codes were marked positively.

Furthermore, of these 81 codes, 70 of them fit the "Broadcast" category laid out by Rowe (Rowe 2005). This category is the one that most resembles older model of science communication and involves little to no two-way engagement with the viewers. Were this mode to be ignored there would be 280 codes remaining, with only 4 % of them being marked positively. As the channels analysed are the most popular of their kind on "YouTube", it can be inferred from this that (in this form of media at least) that the viewing public do not find engagement necessary and may not even desire it.

The most popular science communication channel on "YouTube" is ""VSauce"" with 9.7 million subscribers as of 15/12/2015. This is more than twice that of the next most popular channel. However, despite its popularity, ""VSauce"" participates in almost no engagement with viewers on "YouTube". None of the most popular videos are marked positively in any category other than a basic broadcast.

There is a similar, and marked lack of engagement in the "TED" talks channel. These talks are widely considered extremely popular, with the "TED" videos having been viewed more than one billion times (Tsou et al. 2014). However, there is no attempt to engage with those who view the talks. All of the talks analysed only match the criteria of “broadcast” with none of the other criteria being met once. The format of “TED”, and its lack of continuity of presenter makes it even harder for the speakers to engage with the viewers as they are not the ones running the channel and do not have the same access to the comments and channel that the “TED” team do.

Of the other Dialogue based criteria, the one that was met most often was “Crowdsourcing” (Gough et al. 2014). Crowdsourcing involves members of public using their own money to back the production of certain channels. A common crowdsourcing platform is “Kickstarter”, which allows users to create pages in which they attempt to source a certain set amount of funds by a certain deadline, enticing donations by offering tiers of backer-specific rewards, based on the amount donated. Several channels on “YouTube” use a similar website called “Patreon.” However, on “Patreon”, there is no deadline, and the public pledge a certain amount per project, or per month in exchange for backer rewards. Of the channels analysed, “Patreon” is used by ““SciShow””, ““MinutePhysics”” and ““Smarter Every Day””. Of the videos analysed 9% of them were produced in part by crowdfunding. Of the channels analysed, “SciShow” is the one that most makes use of engagement, with 30% of their videos doing so. The creator of “SciShow”, Hank Green, has been very active in this style of engagement, having founded a similar, now defunct platform “Subbable” and sitting on the board of advisors at “Patreon”. This kind of engagement matches one of the most espoused strategies of the PEST model, which is allowing the public to dictate the direction of science communication, and is a promising way forward in the area.

Following that, the most used mode of dialogue based communication was "Content Creation", or asking the viewers to submit their own content, or responses to videos. Only one channel made use of this method: "Veritasium". "Veritasium"'s presenter and creator, frequently interviews members of the public to show misconceptions about scientific concepts. He states in his video "Why Do You Make People Look Stupid", that if "you just say the correct stuff…viewers don't actually learn anything." For the same reason he often releases videos in two parts, one setting up an experiment, and a second explaining the results. He encourages viewers to respond with their own explanation before releasing video two. Though not a widely used method of dialogue based engagement, it may show some promise. While "Veritasium" ranks 5th in terms of popularity, it ranks 2nd in the number of "likes/dislikes" received. So while it has not attracted as many subscribers as others, those who do watch the channel's videos are more likely to engage, even if it is the small way of publicly liking or disliking the video.

The other two strategies presented, "hotlines" and "polls" were used equally rarely. Both of these communication strategies were used only once in the 70 videos analysed. The poll was used by "ASAPScience" on the topic of colour constancy to determine how viewers perceived the colour of a dress in a photograph that became extremely popular, and not on the public's thoughts of any particular scientific issue. The "hotline", or a video designed to specifically answer a viewer's question, was used by "Veritasium" to explain why various proposed thought experiments on methods to break to speed of light would fail.

While “ASAPScience” video is the most popular on the channel, that is more likely due to the timing of the video, being released when the popularity of the dress photograph was in its peak, and less due to the brief use of a poll. Moreover, only one of “ASAPScience”’s videos feature a poll, suggesting it’s not a mode of dialogue based engagement that was responded to with unusual positivity.

The lack of any noticeable trends, or usage of these dialogue based strategies falls in line with the works of Jensen and Buckley (Jensen & Buckley 2014). The research on the dialogue based strategies suggest that the public do not always desire the same level of engagement, and that level of desire fluctuates depending on how and where they are engaged with. The suggestion then, which follows, is that in an online platform such as “YouTube”, it is low level engagement, without heavy use of dialogue based strategies, that appears to be preferred.

4.3 Literacy Based Strategies

The videos analysed fare much better when looking at the literacy based strategies adopted from the PISA 2015 report. Of the 210 coding parameters, 45 % of them attempted to convey one of the knowledge types to its viewers.

The knowledge type most often conveyed by the videos was Content Knowledge. 65 of the 70 videos attempted to convey this type of knowledge. This is to be expected as the most common methods of science communication often try to simply communicate the facts of science. Some of the video’s that didn’t apply Content Knowledge included a “Smarter Every Day” demonstration of a high-speed camera (a staple device of that channel) and a “Veritasium” video discussing the statistics of “Facebook” pages. So while these videos did not focus on content knowledge, they did at least fall within the scope of the channel.

After Content Knowledge, the knowledge type that was most often discussed was procedural knowledge. Procedural Knowledge was discussed in 34 % of the videos analysed. In most cases the way this knowledge was achieved was by discussing a scientific result, before going into further detail as to how this result was achieved (e.g. “ASAPScience” video “What if You Stopped Sleeping?”). Other methods were also employed; such as visits to laboratories in order to examine how the scientists in these labs go about their research (e.g. “Smarter Every Day”’s Jellyfish Sting in Microscopic Slow Motion). Finally, there was the approach of conduct and following through with a full thought experiment, discussing the physics involved, setting up the parameters and reaching a conclusion (e.g. the “MinutePhysics” video “Immovable force vs unstoppable object”).

The final knowledge type, Epistemic Knowledge, was used very rarely, being used in 5 (or 7 %) of the videos analysed. Moreover, the 5 videos which attempted to convey epistemic knowledge came from only 3 of the 7 channels. One example of a video conveying epistemic knowledge was “Veritasium”’s “World's Roundest Object” in which the presenter attempts to convey to the viewer why the measurement system used in science is defined in the way it is (focussing on the definition of the kilogram). The rarity of this knowledge type may come from how ill-defined it is, with multiple definitions, as discussed by Erduran and Dagher. (Erduran & Dagher 2014)

This data seems to suggest that, as it is content that proves most popular, content may be most wanted strategy by the viewers. That those who watch these videos may simply want to learn more about scientific phenomena, either through facts or through demonstrations.

Overwhelmingly, the knowledge type that popular “YouTube” science channels make use of is Content Knowledge. This would suggest that in the case of “YouTube” science communication, that the public wish to learn more information, to remove any knowledge gaps they may possess, which may be a positive strategy in this arena, as noted by Sturgis and Allum (Sturgis & Allum 2004) that an increase in scientific knowledge often improves the view of science held by members of the public.

4.4 Dissemination Based Strategies

The most used engagement strategies were the dissemination based strategies, with 49 % of 560 coding parameters (8 codes across 70 videos) were marked positively.

Most often marked positively was the “continuity” code. Every channel (apart from the ted talks) maintained a strong continuity of style and of presenter, the ted talks being unable to due to the nature of the format. This affirms the research of Welbourne and Grant (Welbourne & Grant 2015) which state that this is usually a factor present in popular “YouTube” broadcasts, possibly due to the ability of viewers to gain an affection for a particular channel, building a fanbase, and the ease of not needing to become accustomed to a new style of presenting content or a new style of speaking.

Narrative devices were also very commonly used across nearly all the channels analysed. Of the videos analysed, 57 % made use of narrative devices, discussing scientific topics throughout the video, without sudden changes in style of narrative type. Most videos analysed fell into an explanatory style of narrative, as per Van Dijck's narrative types (van Dijck 2006). The explanatory style of narrative can be summed up as "this is how science works." This narrative style is closest to the Content Knowledge type of science literacy. Fewer videos used a reconstructive mode of narrative ("this is what happened"), discussing historical events or the nature of studies. While this often overlapped with Procedural Knowledge, it did not always do so as a discussion of historical events is a reconstructive narrative, but does not necessarily convey Procedural Knowledge. Even fewer videos touched upon the Epistemic Knowledge related Expository Narrative ("this is what science is") and no videos analysed fit a speculative narrative ("this is what could have happened").

Following that, the most often used strategy was "visualisation" with 61 % of the videos positively using that mode of engagement. Across the channels, there were various methods used to assist viewers in visualising a scientific phenomenon. Some channels used computer graphics in order to simulate different views and angles of a problem. Other videos used props to get the message across using everyday items and tools. Another method used for visualisation purposes was a high speed camera. By filming at a much higher framerate than usual, a very different view of the topic came into focus. For example, the "Smarter Every Day" video "TATTOOING Close Up (In Slow Motion)" used the camera to show how tattoo needles and tattooing machines worked, visualising a phenomenon that is too fast for the naked eye to see normally.

Relevance is another commonly used mode of dissemination based engagement, being present in 51 % of the videos studied. The way in which channels made their subject matter varied, but appeared in two main strands. In one case, the video discussed an important global issue (such as cancer, global warming, or in one more flippant case, the possible extinction of the banana plant). In the other case, the relevance was more toward daily life, and how the technology and phenomena that a viewer may experience every day, work (e.g. “MinutePhysics” “What Is Fire?” or the “VSauce” video “Why are Things Creepy”)

The other modes of dissemination based engagement were used less often, having been used in less than 50 % of these. Artistry and Humour were both used in a smaller number of videos (44 % and 30 % respectively). This may be subjective nature of art and humour, as well as the role that “talent” plays in these modes of engagement. This is backed up by the fact that were a channel to use either of these modes, then it was likely that that channel would use that mode heavily. “ASAPScience” and “MinutePhysics”, for example, both rely heavily on artistry, with the videos on both channels being comprised of artwork. Outside these two channels, only 11 of the 50 remaining videos made use of artistry. Humour was also either made use of frequently, or very rarely, depending on the channel. Of the 21 videos coded positively for humour, 10 of them came from “SciShow”. The only channel to be inconsistent in its use of these two codes was the ted channel. This is likely because ted features very different speakers with different levels and predilections for artistry and humour.

The code for dissemination based engagement that was used least was "transparency". Despite the discussions of Fausto et al (Fausto et al. 2012) about how transparency of results and method could unite scientists and the public, it seems possible that the public are not motivated to push for this level of transparency. Only 27 % of the videos analysed made use of this code.

It should be noted that each individual dissemination based code was employed more often that every dialogue based code (excluding broadcast) put together.

This is in line with the work of Baram-Tsabari and Osborne, which state that science communication must be careful of "reinventing the wheel" when focussing on engagement (Baram-Tsabari & Osborne 2015). They suggest that the deficit model cannot be completely ignored, as to do so ignores the real deficit that many do possess. When discussing engagement, it is important to focus on methods that improve how the public obtain their information, as well as how to engage with them in a "two-way" dialogue.

4.5 Conclusion

The results of the thematic video analysis support the works of several authors, pointing to a conclusion that the deficit model cannot be wholly eliminated. These channels all possess millions of subscribers, and have been viewed tens of millions of times. The analysis points to a public, whom in this instance, do not actively engage with the content creators, and in this instance, may not wish to. In this arena, the public may wish for a lower level of engagement, as suggested by Jensen and Buckley (Jensen & Buckley 2014). Further analysis also points to a public who respond to dissemination based models of public engagement. These models are used to improve how the public receives the information and are largely "one-way". This supports the idea spoken of by Baram-Tsabari and Osborne (Baram-Tsabari & Osborne 2015) that when communication science, the information deficit model cannot be wholly ignored, that the public may wish to learn, and seek to fill in any gaps in their knowledge themselves.

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Chapter 5

Thematic Discussion Analysis

In this chapter, the results of the thematic discussion analysis will be presented, this includes both the codes generated as part of this "open-ended" study, and the prevalence of those codes in both a number of popular "YouTube" videos, and a number of articles for the popular science "Facebook" page: "I F*cking Love Science". These results will also be discussed independently and in context with the Thematic Video Analysis of Chapter 4.

5.1 Codes Generated and Rationale

Upon completion of the discussion analysis, the codes that were generated were as follows:

Table 5.1: Summary of Generate Codes.

	Comment Codes
1	Comment/opinion about subject matter
2	Request
3	Further Scientific Information
4	Further Scientific Information (from creator)
5	Creator Comment
6	Disagreement with content (anecdotal)
7	Disagreement with content
8	Disagreement with content (scientific)

9	Anecdote
10	Unrelated Comment/question
11	Non-scientific question about content
12	Scientific question about content
13	Question about video or channel
14	Question about presenter
15	Positive Comment about presenter
16	Negative Comment about presenter
17	Positive Comment about video/article (scientific)
18	Negative Comment about video/article (scientific)
19	Positive Comment about video/article
20	Negative Comment about video/article
21	Joke/Pop Culture Reference
22	Shares
23	Spam
24	Non-English

While many of these codes are self-evident, some could benefit from further explanation.

Code 1) "Comment/opinion about subject matter". Often, commenters discussed events occurring in the video in a tangential manner, commenting on the content without ever mentioning the events, or science, taking place in the video. For example, in a video discussing the application of tattooing, a large number simply commented on their opinion (both positive and negative) of tattoos, or contemplating how much it may hurt. Another example is that in an article about using drugs for Parkinson's disease to treat chronic pain, several comments simply referred to this being a positive, with no further thoughts shared. Comments which were related to the content, but not the scientific content, were sorted into this code. Originally, this code was separated into positive comments or opinions, and negative comments or opinions. However, as these comments were not reflections on the creators, or the science discussed by the creators, it was deemed unnecessary to do so.

Code 2) If the comment requested a video concerning a certain topic, it was sorted into this code.

Codes 3 – 4) If any aspect of the video was expounded upon and explained further, it was sorted into this category. It was also noted whether it was by a commenter, or by the creator of the video, to determine the primary “direction” of the dialogue.

Code 5) Any creator comment that didn’t further the scientific understanding of the video was sorted here. For example, in the “ASAPScience” video “What Colour is This Dress” there were two comments asking viewers to vote as to whether they saw the dress as blue and black, or as white and gold.

Codes 6 – 8) “Disagreement with content of video”. There are three variations of this code. Commenters could simply disagree with the content (“I don’t think that’s correct”), they could disagree with use of an anecdote (“I don’t think that’s correct because once…”), or they could disagree with use of a scientific argument (I don’t think that’s correct, there’s another principle in effect here…”). This separation was done to examine if commenters wished to argue the science, share personal experience, or simply disagree with the video.

Code 9) Anecdote: If the comment was primarily a story or statement from personal experience it was sorted into this code.

Code 10) This code was selected if the comment or question was totally unrelated to the subject matter. (e.g. A comment discussing car engines in a video on tattooing)

Codes 11 – 14) Codes 11 to 14 all regarding questions being posted to the video under varying circumstances.

- Code 11 entails questions asked about the content, but not the scientific content. ("Where would I purchase a dress like that" or "Does getting a tattoo hurt?").
- Code 12 deals with questions in which the commenter is attempting to learn more relevant, scientific information (e.g. "How is a gun able to fire underwater?").
- Code 13 is selected if the question is concerning the video or channel ("What camera is used to film this?" or "How many writers do you have on staff?")
- Code 14 is for personal questions regarding the presenter. ("Where do you get your ideas?"

Codes 15 – 20) These deal with positive and negative opinions towards the presenter, channel, or video/article. Comments directed towards the presenter are often personal, Complimenting some aspect of their appearance or lifestyle. Remarks towards the channel, are again, either complimentary or disparaging how the channel is run, or the overall writing style. Comments towards the video/article were split into two categories. One deals with scientific comments ("I like/do not like how you carried out that demonstration"), or not scientific ("The article title is very misleading")

Code 21) If the comment was nothing but a joke, or pop culture reference, it was deemed to fit into this code. Comments that contained content other than this were sorted elsewhere.

Code 22 – 24) These codes are for comments that are absolutely unrelated, or unusable. Code 2, "Shares", is for a comment that does nothing but mention another user, in an attempt to bring the article or video to their attention. Code 23 is for spam messages and Code 24 is for messages in languages other than English

It was also noted whether the comment generated any kind of discussion. If the predominant focus of the discussion, as interpreted by the researchers, was coded separately into a group of discussion codes. These codes were to determine how people interacted with each other within this media. Were the comment discussions, or "threads" primarily discussing the science of the video, either to answer questions or to debate the topic or were they simply discussing content, or were they unrelated totally (and often insulting). There were also codes for whether the replies to the comment were nothing but agreements with the original comment ("So right", "I think the same", "Ha", etc).

The discussion codes were:

Table 5.2: Summary of Discussion Codes

1	**Scientific Debate**
2	Scientific Question answered
3	Content Related Discussion (non-science)
4	Anecdotal Discussion
5	Advice
6	Unrelated Discussion
7	Agreement

5.2 Results of Thematic Discussion Analysis

Once the comments had been analysed and coded, several themes emerged from the data.

The first includes all comments that attempted to engage with the scientific content of the video or article. This included those who posted further scientific information, be they viewers or creators. It also included those who asked scientific questions or requested new videos, in an attempt to learn and see new scientific information (The relevant codes are; 2, 3, 4, 8, 12, 17, and 18.) of the 300 comments analysed, only 28% fitted somewhere into this theme.

Another relevant theme was viewers who engaged with the content, but not with the scientific information within that content. It also included those comments which asked questions related to the content, that were not attempts to learn more scientific information. The relevant codes for this theme are; 1, 11, and 21. Of all comments analysed, 53% fell into this category.

A related theme is the anecdotal theme. This theme encompassed any attempts to share personal experience or advice through comments (the relevant codes are 6, and 9). A total of 14 % of the comments were primarily anecdotal.

There was also present a dialogue based theme. Comments which attempted to actively start a dialogue, either about the science or the related content. This dialogue could come from two directions. The first is a comment from the creator of the video attempting to generate discussion from the viewers, this could come from further information about the science in the video, by starting a poll, or simply discussing the other content of the video. The codes that best fit this direction of dialogue are 4, and 5. Less than 2 % of all comments were from the creators of the content.

There are also comments wherein the commenter is attempting to start a dialogue, either with the creator of the content, or with other viewers of the video. This code included comments that asked advice, asked opinions, orasked questions about the science or content of the video. 16.67 % of the comments attempted to create dialogue in this way.

The final "theme" grouped together anything unrelated or that couldn't be parsed (Codes 22, 23, and 24). 6.67 % of all comments fit this category.

Of the comments analysed in this study, only 44 % of them had any replies with which to start a discussion (133 in total). There was a much higher rate of reply on "YouTube" with 64 % of comments spawning discussions, and only 24.67 % of "Facebook" articles doing so.

Of these discussions, 15 % of them were either further scientific discussions of the content (10.5 %), or answering a scientific question posed in a comment (4.5 %). The most common kind of discussion were those that discussed the content, but not the scientific content. This type of discussion formed 37 % of all discussions. A further 17 % of the discussions were anecdotal, with commenters exchanging personal experiences and stories. Simple agreements with a comment constituted 20.5 % of the discussions. Advice was given by other commenters in 3 % of cases, and utterly unrelated comments and derogatory conversations formed 7.5 % of discussions

5.3 Discussion of Results

All the videos and articles studied here are very popular. As of 19/12/15, every video has at least 17 million views and every article (as of 27/12/15) published has tens of thousands of "Facebook" "likes" and reactions. However, despite the obvious popularity of these videos, dialogue is not a priority, with neither viewers, nor creators heavily engaging in dialogue. Of the 300 comments analysed, only 5 came from the creators of the video. Moreover, across all the videos, a creator only replied to a comment once, in the "Veritasium" video "Surprising Applications of the Magnus Effect". This reply was a discussion of the principles at play as the original comment disagreed with the video's interpretation of the Magnus effect.

Beginning a dialogue is not a priority for the viewer either, as less than half of all comments spawned dialogues. This suggests that the public desire quite a low level of engagement when it comes to online media. It suggests that what the public may want to is be heard, and to share opinions and personal stories, and may want less to engage with the science being presented. Not only is the desired level of engagement lower than in other avenues of science communication, it is lower across the discussion analysis. Dialogues were far less frequent on "Facebook" than they were on "YouTube" and the length of these dialogues was often much shorter, suggesting an even lower level is desired on "Facebook" than on "YouTube".

Moreover, it should be noted that in one channel, "ASAPScience", every video asks if the viewers have a questions they want answered, and if so, to post it in the comments of the video. However, when the comments were analysed, only 6 comments were questions, and none of those comments were questions about science. Also, none of these questions were answered by the creators of the video.

This reinforces the results of Chapter 3, and the work of Jensen and Buckley (Jensen & Buckley 2014) suggesting strong importance in understanding that desired levels of engagement can change drastically depending on the medium. The desired level of engagement can even change between different websites.

However, that is not to say that engagement is never used to positive effect. In the "ASAPScience" video "What Colour is This Dress", the creators commented twice, telling viewers to vote on which set of colours they saw a particular dress as being (either blue and black, or white and gold). As of 27/12/15, each of these comments had more than 30,000 "likes" each and more than 500 replies each, well above the norm (Although the content of these replies was almost exclusively Agreements, with commenters cheering on their respective "team"). This further suggests that in this space, the public wish to be heard by those communicating the science, and that perhaps a more comprehensive typography of public engagement could be derived, as argued by Rowe (Rowe 2005). A new typography could possibly include a new variety of modes to allow for online science communication.

However, despite the low levels of engagement with the content shown, there is clearly a much higher level of consumption. With the tens of millions of views and the tens of thousands of reactions, the science being communicated is clearly popular. This suggests that the public are keen to learn and to fill gaps in their knowledge. Therefore, as put forward by Baram-Tsabari & Osborne (Baram-

Tsabari & Osborne 2015) that aspects of the information deficit model should be retained as the public do seek to learn new information, provided it is presented in an appealing manner.

5.4 Discussion of Results in Context

The results of Chapter 4 reinforced by the results of this analysis. The low levels of dialogue from both the viewing public, and the creators of the content point to a desire for a "first-order", dissemination based model of engagement, as discussed by Irwin (Bucchi et al. n.d.). It appears to be the content's use of dissemination based strategies that primarily point to popularity.

As said previously, both Chapters 4 and 5 point to a low level of desired engagement. However, dialogue based engagement can be achieved online to great success. This is shown in the video analysis through an effective use of crowdfunding, or in successfully requesting video responses from viewers. This is reinforced in the discussion analysis by the high number of "likes" and comments received whenever the creator of the video comments themselves. This indicates that the key to effective engagement online, be it through dissemination, or dialogue, is not in forcing one model. The key appears to be having a sufficiently thorough typology as suggested by Rowe (Rowe 2005) as to understand what the public are requesting from the science communication they consume online.

Furthermore, both the video, and discussion analysis point to a desire to learn and to fill deficits in knowledge. As shown in Chapter 3, popular videos attempt to convey at least one type of scientific knowledge (usually content knowledge). In Chapter 4, it can be inferred that viewers and readers are paying attention to the content. Comments are primary anecdotal or related to the non-scientific aspects of the video, however, that still implies that attention has been paid and the choice of the viewer is to not engage any further scientifically, as the level of engagement they are looking for has been reached. This points to the argument of Baram-Tsabari and Osborne (Baram-Tsabari & Osborne 2015) which suggests that it would be premature to disregard the information deficit model entirely.

5.5 Conclusion

In conclusion, the results of the discussion analysis, as presented here, reinforce the results of the video analysis and support the trend in the literature that public engagement is both not described succinctly enough in the literature and may not be desired to the same extent across all platforms. This points to a need for a strong, well defined typography as suggested by Rowe (Rowe 2005)

Both analysis chapters support an understanding that there are varying levels of literacy and engagement, as per Jensen and Buckley (Jensen & Buckley 2014). The findings from these studies also support the idea that elements of the so-called deficit model should be maintained as there are

in their knowledge base, as supported by the writing of Baram-Tsabari and Osborne (Baram-Tsabari & Osborne 2015).

In the next chapter, the conclusions of the work will be summated and presented, together with the context of this work within the literature.

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Chapter 6

Conclusions

Over the course of this research, numerous conclusions as to the nature of public engagement in an online space have been reached.

Firstly, it has been shown through thematic analysis, that the public to not seem to be pushing for a higher level of engagement online, and a dissemination (first-order) approach is the most popular. Through the discussion analysis it was shown that the desired level of engagement varies even across different science communication websites, with a much higher level of engagement preferred on “YouTube” than on “Facebook”. This is in line with the work of Jensen and Buckley, as discussed previously (Jensen & Buckley 2014).

As discussed in the Literature Review, PUS and PEST do not exist independently of one another, in two separate spheres. The former evolved into the latter. However, the results demonstrate that meaningful communication can be achieved at all points across the spectrum from PUS to PEST, whether it be tradition, speaker based, “first-order” communication, like that of TED, or dialogue and community based engagement, like those created by Derek Muller and Hank Green. The success that can be had communicating from any point along the spectrum reinforces an important point: That no singular form of science communication is intrinsically "better". All points in the evolution from PUS to PEST have their place, and that perhaps it would be better to consider them as different tools for different problems, as opposed to competing theories.

The highly variable nature of the desired level of engagement suggests that a robust typology of engagement mechanisms needs to be discerned. As two-way engagement strategies have been successful online, the onus is on communicators to determine how best to use these mechanisms, having a thorough understanding of this new typology. This supports the argument for a new stronger typography put forward by Rowe (Rowe 2005).

A new typography must also include the idea that when engaging online, the public are attempting to resolve deficits in their knowledge, and therefore, it may not be wise to "reinvent the wheel" and entirely discard the information deficit model (Baram-Tsabari & Osborne 2015). Furthermore, discarding the deficit model may also be unwise as if communicators are to build trust, it must be mediated by knowledge (Sturgis & Allum 2004).

The videos and creators analysed in this project all have massive followings, each with subscriber counts of more than one million. Whether the channel or page uses different types of dissemination, or dialogues, or combinations thereof, popular science communication can be achieved. This supports the hypothesis put forward in Chapter 2, that no single point on the dissemination-dialogue continuum is inherently better than any other point. The results show that successful science communication (successful at least in terms of view count) can be achieved through a variety of different methods. For example, Vsauce uses virtually no engagement, whereas Veritasium relies heavily upon it, and yet both channels remain incredibly popular, both with rapidly increasing subscriber counts.

Following on from this, there is no obvious trend of movement from one style of engagement to another, in either direction on the continuum. Channels like SciShow continue to use crowdfunding platforms as their main sources of engagement while other channels choose different strategies as mentioned in the previous paragraph.

The high popularity across all modes of engagement reinforces the hypothesis that perhaps the publics, or at least those publics as defined by those who frequently use this form of media, appear to be happy with varying modes of engagement, not necessarily preferring one to another.

This is not to say however, that these modes do not have their own value. As shown by the uptake of Patreon, and by the engagement present on Veritasium, when the format presented is one where engagement is obviously encouraged, then viewers will begin a dialogue. However, the lack of this dialogue in itself does not dissuade viewers from continuing to enjoy the information presented.

Finally, these engagement strategies must be well understood and the public desires must also be understood even if they may be uncommon, or as warned by Irwin, science communication may continue to be unable to accept criticism.

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Appendix

Links to videos and articles
Thematic Analysis:

Vsauce	
What if Everyone Jumped at Once	https://youtu.be/jHbyQ_AQP8c
Why Do We Kiss	https://youtu.be/ixQbCXLUUj8
Is Your Red the Same As My Red	https://youtu.be/evQsOFQju08
Guns in Space	https://youtu.be/hYf6av21x5c
This is Not Yellow	https://youtu.be/R3unPcJDbCc
What Colour Is A Mirror	https://youtu.be/-yrZpTHBEss
How High Can We Build	https://youtu.be/GJ4Qp2xeRds
What's the Most Dangerous Place On Earth	https://youtu.be/1T4XMNN4bNM
Travel INSIDE	https://youtu.be/3pAnRKD4raY
Why Are Things Creepy	https://youtu.be/PEikGKDVsCc
TED	
My stroke of insight	https://youtu.be/UyyjU8fzEYU
10 Things you didn't know about orgasm	https://youtu.be/7jx0dTYUO5E
Underwater astonishments	https://youtu.be/YVvn8dpSAt0
The surprising science of happiness	https://youtu.be/4q1dgn_C0AU
Questioning the Universe	https://youtu.be/xjBIsp8mS-c
Conception to birth - visualised	https://youtu.be/fKyljukBE70
Why do we sleep	https://youtu.be/LWULB9Aoopc
A promising test for pancreatic cancer	https://youtu.be/g-ycQufrgK4
Optical Illusions show how we see	https://youtu.be/mf5otGNbkuc
Can we eat to starve cancer	https://youtu.be/B9bDZ5-zPtY
ASAPScience	
What Colour is this Dress	https://youtu.be/AskAQwOBvhc
Which Came First - The Chicken or the egg	https://youtu.be/1a8pI65emDE
How old are your ears (Hearing test)	https://youtu.be/VxcbppCX6Rk
Brain tricks - This is how your brain works	https://youtu.be/JiTz2i4VHFw
The NEW Periodic Table Song, in order	https://youtu.be/VgVQKCcfwnU
Amazing Facts to blow your mind - Pt2	https://youtu.be/6Ni5HOdGtzM
Childbirth vs Getting Kicked in the balls	https://youtu.be/FJeuK1Pl2bQ
Amazing Facts to blow your mind - Pt1	https://youtu.be/cKZStlBECHo
What if you stopped sleeping	https://youtu.be/nNhDkKAvxFk

Does penis size matter	https://youtu.be/BK3SXjJ5Zog
Minutephysics	
Immovable force vs unstoppable object	https://youtu.be/9eKc5kgPVrA
how to see without glasses	https://youtu.be/OydqR_7_DjI
is it better to walk or run in the rain	https://youtu.be/3MqYE2UuN24
what if the earth were hollow	https://youtu.be/jN-FfJKgis8
the true science of parallel universes	https://youtu.be/Ywn2Lz5zmYg
schrodingers cat	https://youtu.be/IOYyCHGWJq4
why is the solar system flat	https://youtu.be/tmNXKqeUtJM
there is no fourth dimension	https://youtu.be/M9sbdrPVfOQ
why is it dark at night	https://youtu.be/gxJ4M7tyLRE
what is fire	https://youtu.be/1pfqIcSydgE
Veritasium	
Surprising Applications of the Magnus Effect	https://youtu.be/2OSrvzNW9FE
World's Roundest Object	https://youtu.be/ZMByI4s-D-Y
Anti-Gravity Wheel	https://youtu.be/GeyDf4ooPdo
Pyro Board: 2D Ruben's Tube	https://youtu.be/2awbKQ2DLRE
Can Silence Actually Drive You Crazy?	https://youtu.be/mXVGIb3bzHI
Can You Solve This	https://youtu.be/vKA4w2O61Xo
Facebook Fraud	https://youtu.be/oVfHeWTKjag
The Most Radioactive Places on Earth	https://youtu.be/TRL7o2kPqw0
Will This Go Faster Than Light	https://youtu.be/EPsG8td7C5k
5 Fun Physics Phenomena	https://youtu.be/1Xp_imnO6WE
SciShow	
The Truth About Gingers	https://youtu.be/QNJkcr7u2TY
Top 5 Deadliest Substances on Earth	https://youtu.be/2z35_1e1MtI
The Science of Lying	https://youtu.be/MX3Hu8loXTE
The Deepest Hole in the World	https://youtu.be/zz6v6OfoQvs
The Science of Overpopulation	https://youtu.be/dD-yN2G5BY0
Why Sexy is Sexy	https://youtu.be/ZYUtVsA-wi4
The Terrifying Truth About Bananas	https://youtu.be/ex0URF-hWj4
Your Brain On Porn	https://youtu.be/jE6ve14MIk4
How Weed Works:THC	https://youtu.be/FsJzCdFlpyQ
5 Animals That Aren't Dinosaurs	https://youtu.be/ly8K257P2BI
Smarter Every Day	

TATTOOING Close Up (In Slow Motion)	https://youtu.be/kxLoycj4pJY
How Houdini DIED (In Slow Motion)	https://youtu.be/QJ9lNRAjTQM
Ak-47 Underwater at 27,450 frames per second	https://youtu.be/cp5gdUHFGIQ
The Backwards Brain Bicycle	https://youtu.be/MFzDaBzBlL0
Slow Motion Flipping Cat	https://youtu.be/RtWbpyjJqrU
Mystery of Prince Rupert's Drop at 130000 fps	https://youtu.be/xe-f4gokRBs
A baffling Balloon Behaviour	https://youtu.be/y8mzDvpKzfY
Jellyfish Sting in Microscoping Slow Motion	https://youtu.be/7WJCnC5ebf4
High Speed Fun and a Fly Responding to a Blast wave	https://youtu.be/QH091zFHdQ0
High Speed Video of Pistols Underwater	https://youtu.be/_eUlpPY96Ok
Discussion Analysis YouTube:	
TATTOOING Close Up (In Slow Motion)	https://youtu.be/kxLoycj4pJY
Surprising Applications of the Magnus Effect	https://youtu.be/2OSrvzNW9FE
How Houdini DIED (In Slow Motion)	https://youtu.be/QJ9lNRAjTQM
What Colour is this Dress	https://youtu.be/AskAQwOBvhc
Ak-47 Underwater at 27,450 frames per second	https://youtu.be/cp5gdUHFGIQ
Facebook:	
There are actually 12 Different Types of Rainbow	https://www.facebook.com/IFeakingLoveScience/posts/1285297504824591
NASA Will Test Growing Potatoes in Mars-like Environment	https://www.facebook.com/IFeakingLoveScience/posts/1285295808158094
How Evil Are You?	https://www.facebook.com/IFeakingLoveScience/posts/1276710892349919
Parkinson's Drug Could Treat Patients with Chronic Pain	https://www.facebook.com/IFeakingLoveScience/posts/1285297271491281
Here's What Compulsive Gaming Does to Your Brain	https://www.facebook.com/IFeakingLoveScience/posts/1285302054824136