DUBLIN CITY UNIVERSITY

Engaging with Online Audiences

A cross-country analysis of use of the Web for communicating biomedical science to public audiences

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I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of MA, Science Communication is entirely my own work, 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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Dedication

Many thanks to my supervisor Brian Trench for sharing his knowledge and time with me and for enabling me to accomplish this body of work.

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Abstract

This research project is an examination of the websites of biomedical research institutes to identify the extent to which the Web is used to communicate science to public audiences. Through a review of the literature, it was found that biomedical research institutes can communicate information effectively by targeting content at particular segments of their audience; providing in-depth yet accessible information; endeavouring to take an open approach to communication, in order to build trust, which does not attempt to shield the public from uncertainty; and blending different approaches to, or models of, communication.

This research was accomplished through a content analysis of the websites of 68 biomedical research centres in the United Kingdom, Ireland, United States, Canada and Continental Europe. The websites were examined for their attribution and transparency; content and currency; interactivity and navigation; design; and accessibility. Further data was obtained through questionnaires from communication practitioners in the institutes in order to validate content analysis results.

Research has shown that biomedical research institutes in the United States surpass the other countries in their efforts to communicate with public audiences via the Web. Of the five highest scoring websites, four were located in the United States. On a whole however, the public communication of biomedical research does not appear to be the primary aim of online communication and the deficit model is still widely used with very little opportunity provided for user discussion or interaction.

1: Introduction and Aims

The public understanding of science field has developed based upon a principal objective of increasing public awareness for and appreciation of science. Developments in the field have led to a deeper understanding of the 'public', recognising that it is a varied and diverse group. In better understanding the diversity of public audiences, the public understanding of science movement has formed a greater understanding of the role of science communication in informing public audiences and the positive impact that an informed public can have on society. A number of approaches to or models of, science communication have emerged over recent decades which have sought to identify the most effective means of communicating with and having an impact on this diverse public.

As it has developed over time, the Web has become a powerful tool for communication, connecting people previously divided by geographical, social and economic boundaries. Over the past two decades, access to the Web has undergone rapid growth across the globe. Not only are more individuals accessing the Web but they do so more frequently through mobile devices which make it possible to be 'connected' from just about anywhere. The PEW report in 2006 showed that 40 million Americans rely on the Web as a primary source for news and information about science and that the Web is the source people turn to first when they need information on a specific science topic.

With its inherent properties of transparency, accessibility and ease of use, along with the emergence of interactive online technologies, the Web offers scientific research institutes a unique opportunity to engage with audiences through the medium of an institute website. While the Web presents a powerful means of communicating with a variety of audiences, mere presence online is not enough to ensure that audiences are reached or satisfied. A number of key points must be addressed in order for online presence to deliver effective communication.

1.1: Purpose of Study

At the beginning of this research project I was interested in discovering ways in which the Web was being used as a tool for the communication of science by biomedical science research institutes. I was particularly interested in the extent to which these institutes were using the Web to communicate with public audiences. Biomedical Science was selected as the specific field of science in part because of my work in the field, however given the close relationship between biomedical science research and medicine, the level of public interest in research outputs and translation to new therapies acts to increase the demand for public communication placed upon the field. Ethical implications that emerge from contentious areas of biomedical science, of which stem cell research is one example, places an expectation on biomedical science institutes to share details of their work with public audiences. This increased demand places pressure on scientists working in the field of biomedical science to participate in public communication activities and to make available information on their work. For these reasons, an examination of the work done by biomedical science research institutes to address the issue of public communication is of particular interest.

In addition to gaining a greater understanding of use of the Web for public communication of science, an early aim of the project was to create a set of best practice guidelines for the development of Web content that could be used to aid communications practitioners working in the field of science.

The study had three objectives:

1. To determine the extent to which the Web is used by biomedical research institutes as a means of communicating their research to public audiences
2. To examine ways in which use of the Web by science research institutes differs between countries
3. To establish a set of best practice guidelines for the development of science websites.

To achieve these three objectives, a number of methods were used to derive a more substantive picture of current practice. Methodological triangulation facilitated validation of data through cross verification of three sources. The methods used were literature review, content analysis and survey questionnaires. Based upon findings in the literature review, the content analysis coding framework was developed. In conducting the content analysis, a series of hypotheses were put forth. Like the work of previously conducted studies by Ledgerbogen and Trebbe (2003), Trench and Delaney (2004), Massoli (2007) and Jaskowksa (2008), I expected to find that overall, biomedical research institutes used the Web to communicate with the scientific community more so than with public audiences. I hoped however to find examples of institutes which targeted Web content to specific public audiences; provided an in-depth look at the research conducted in the institute; and made use of Web technology to enable a dialogic approach to communication with public audiences. Having carried out the content analysis, some though not all of these hypotheses would be proven to be true. Survey questionnaires of the communication practitioners responsible for the content analysed were then conducted to validate those findings.

1.2: Significance of Study

The Web has become one of the most commonly used tools of communication adopted by science research institutes. Nearly all science research institutes have a website. The way in which that website is used however, differs greatly from one institute to the next. While some see the Web as a means of broadcasting the results of their scientific research projects and latest findings in the labs, others see it as a convenient way to share contact information and little else. Not only does content vary greatly from one site to another, the audience for whom that content is intended, and in turn prepared, also varies. This study is a cross-country analysis of biomedical science institutes' use of the web for public communication.
Previous research conducted to analyse use of the Web for science communication will be examined. The work of Lederbogen and Trebbe (2003), Trench and Delaney (2004), Massoli (2007) and Jaskowska (2008) will be examined to assist in the development of an evaluative coding framework for content analysis and to gain an understanding of previously identified trends and patterns in science communication on the Web. Findings of these studies are explored in the literature review.

My research is relevant to communications practitioners who are currently exploring ways of increasing and improving their methods of communicating science research findings and information with a range of public audiences. It is hoped that the results of this thesis will promote the use of the Web for the public communication of science and assist in the selection of suitable methods to ensure maximum inclusion of a wide range of public audiences using a variety of communication models and Web technologies.

The second group identified was academic researchers for whom this research has implications as it adds to the current body of research on use of the Web for the public communication of science by adopting a cross-country analysis approach to the examination of Web use by biomedical science research institutes.

1.3: Personal Experience

Prior to undertaking this research project, and throughout its duration, I was involved in the field of science communication through my work as a communications officer for a biomedical engineering research institute at the National University of Ireland, Galway. In that role, I have been responsible for the institute's external communication, a significant portion of which is carried out through the institute website. It was this role which prompted me to explore existing public communication of science practices on the Web and led me to begin this body of research. Knowledge gained through the work carried out for this study has had a direct impact upon my efforts to communicate my colleagues' scientific research findings with public audiences through our website. During the course of this research, I carried out a redesign of the website, and have had the opportunity to put into practice the information gained through both the literature review and content analysis results.

The website of my own research institute has not been included in this study as self-evaluation may have produced a biased result. It should be noted that two institutes included in the sample are associated with that in which I work, the Regenerative Medicine Institute (Remedi) which is based in NUI Galway and the Centre for Bioanalytical Science (CBAS) which was a collaborative institute between NUI Galway and Dublin City University. I was not involved in the creation of either of these websites, nor have I assisted at any stage in the development of their content.

Chapter 2: Literature Review

2.1 Science Communication

2.1.1: Introduction—the Public Communication of Science

From an early stage in the development of the public communication of science field, the public's ability to understand science was viewed as critical. This central concern was reflected in the use of the phrase 'public understanding of science' as the umbrella for a range of activities in Britain from the mid-1980s onwards. These activities stemmed from the 'Bodmer Report'[1] which led to the development of the Committee on the Public Understanding of Science (CoPUS). The aim of CoPUS was to increase the public understanding of science in order to improve public acceptance of and support for science.[2]

The criticism of these activities that was to follow was based on what Wynne first referred to as the 'deficit model' approach to science communication. Wynne (1989, pg. 38) asserted that when scientific experts assume a "deficit (i.e. inadequate) model of communication and public understanding of science... a universally valid body of scientific knowledge is diluted, distorted, and often undermined by the lay public and media." The deficit model used was a one-way, top-down communication process which placed scientists in the role of having to correct the knowledge deficit of the scientifically illiterate public (Wynne, 1991). As Gross (1994, pg. 12) stated, the deficit model assumed "public deficiency, but scientific sufficiency." The CoPUS approach is considered a failure by many due to its misunderstanding of 'the public', the relationship between knowledge and attitudes, means of relationship building and development of trust (Wynne, 1992, 1995; Irwin 1995; Doble, 1995; Felt, 2000; Wilsdon and Willis 2004; Einsiedel, 2000, 2007).

By the late 1990s new approaches that considered the importance of social context and lay knowledge in determining how science is used by the public began to emerge. Focus on increasing the public understanding of science then began to wane, as new, more contextual approaches to science communication emerged that supported a more dialogical approach. This approach recognised that while scientists may have scientific facts at their disposal, members of the public possess local knowledge and an understanding of, and personal interest in, the problems to be solved (Wynne, 1995; Irwin, 1995; Miller, 2001).

[1] 1985 publication of the Royal Society report prepared by Sir Walter Bodmer

[2] See http://www.CoPUSproject.org/, last accessed March 23, 2009

Alongside these contextual approaches to science communication, a number of definitions of 'the public' began to emerge which sought to move beyond the idea that the public were "an empty vessel... in need of scientific information in order to be replete" (Gregory and Miller, 1998, pg. 17) but rather a diverse and varied group with individual knowledge worthy of consideration. These definitions are useful for identifying the many intended audiences of the science communication movement and will be examined further in this chapter.

The public's ability to understand science, the need to measure civic scientific literacy and the significance of empirical data has been debated in the literature with J.D. Miller (1992; 1998; 2000) arguing that the attainment of scientific literacy is imperative to maintaining a healthy democracy in part as it "increases the proportion of citizens who are sufficiently literate to participate in the resolution of public policy disputes over issues involving science or technology" (J.D. Miller, 1998, pg. 203) while Shamos (1995) questions the need for a civic literacy as well as the public's ability to attain what he describes as *true* scientific literacy. These and other viewpoints will be examined along with the key findings of a number of studies measuring levels of scientific literacy conducted in the UK, Europe and North America.

The relationship between understanding of science and positive attitudes toward science was once thought to be positively correlated. This assumption has been challenged in the literature with theories emerging that range from the acceptance that there is a vague relationship between knowledge and attitudes (Evans and Durant, 1995), to dismissal of the concept as too simplistic an approach (Peters, 2000). A number of these theories will be looked at in greater detail.

One key determinant of the public's attitude toward science and technology is the credibility given to scientists or experts, based largely on trust. The approach taken by science communicators is seen as critical to relationship building and the establishment of trust. Open communication of all information, even when uncertainty emerges (Shapin, 1992; Doble, 1995; Irwin, 2007) and the involvement of the public through a dialogical model of communication (Valenti and Wilkins, 1995) are two approaches put forth. These and others will be addressed in this chapter.

A number of models of science communication have developed over time, each presenting a particular approach toward sharing scientific knowledge with the public. With the introduction of new approaches however, an assumption was formed that older approaches were in need of replacement, an idea promoted by the 2000 House of Lords Report. This assumption has been questioned however, and a blend of approaches rather than a replacement of one with another has been suggested as the way forward (Wynne, 2006; Trench, 2008; Irwin, 2008). These arguments will be examined to discover the basis of each approach and to determine whether or not a change from the deficit model to the dialogue model has indeed occurred.

2.1.2: Who is 'The Public'?

As the literature shows, attempting to define the public or publics is not a simple task. An important early definition of the public is Habermas' (1989). He states that the very use of the terms 'public' and 'the public' is a betrayal of the array of their competing meanings. One potential definition of the public emerging from this work is that the public are "active citizens involved in the public sphere", the social arena in which meanings are "articulated, distributed and negotiated."

As referred to in the field of science communication, the term public is used to refer to citizens without a background in science, often termed a lay person or lay citizen. Early science communication models are based upon this view of the public. It was not long however before this view was challenged, and it was put forth that public lay citizens, while perhaps not possessing a scientific background, nonetheless possess expertise in given areas (Wynne, 1995; Irwin, 1995). As Wynne and Irwin articulate, this individual knowledge shapes their understanding of science and technology, influencing the way they approach the field, and cannot be ignored when measuring the public understanding of science.

In his work measuring the scientific literacy of the public, J.D. Miller (1992, pg. 24) classifies the public into three groups based upon their interest in and engagement with science. He defines the groups as;

- The *attentive* public consists of those who (1) express a high level of interest in a particular issue; (2) feel very well informed about the issue; and (3) read a newspaper on a daily basis, read a weekly or monthly news magazine, or read a magazine relevant to the issue.
- The *interested* public consists of those who claim to have a high level of interest in a particular issue but do not feel very well informed about it.
- The *residual* public consists of those who are neither interested in nor feel very well informed about a particular issue.

His concept of the attentive public is in line with Wynne and Irwin's concept of citizens possessing expertise in given areas. J.D. Miller notes that "there is an attentive public for almost every issue" and that attentive citizens are "better able to receive and process new information" about a given policy area. In acknowledging the expertise of the attentive public, one can begin to understand the basis of attitudes toward science.

Einsiedel (2000, pg. 206) feels the public needs to be viewed within context. She cites a definition of the public put forth by Dewey[3] "that there are many publics, each consisting of individuals who, together, are affected by a particular action or idea, which suggests that the public are always shifting, that every issue creates its own public". This sits in agreement with a definition of the public by Irwin and Michael (2003) that "publics are a complex and heterogeneous set of actors and relations that arise from particular contexts."

Burns et al. (2003, pg. 184) agree with the heterogeneity of the public and further J.D. Miller's categorisation of the public. They define the public as "every person in society," and identify four overlapping groups "each with its own needs, interests, attitudes and levels of knowledge;"

- Scientists- in industry, the academic community and government.
- Mediators- communicators (including science communicators, journalists and other members of the media), educators, and opinion-makers.
- Decision-makers- policy makers in government, and scientific and learned institutions.
- General public- the three groups mentioned above, plus other sectors and interest groups (for example school children and charity workers).

In addition to these groups, they concur with J.D. Miller's (1997) definition of the attentive public and the interested public.

Durodié (2004, pg. 86) also acknowledges the complexity of the public in his very strong opinion stating that "the public are neither particularly insightful... nor are they particularly stupid. They are quite often ignorant of the facts and usually unmediated in their response to them, displaying an understandable proclivity to prioritise emotion over reason." His suggested means of handling the public's involvement in science is as such: "[w]e should accordingly neither condemn nor dismiss them; nor, however, should we celebrate their views or pander to them. The greatest respect you can pay anyone in any form of debate is to challenge their understanding with a view to transcending it or moving on." Durodié's arguments against what he identified as an emerging trend toward dialogue was based on his disagreement with the notion that the validity of scientific knowledge can be democratically decided and the possibility that it may free policy makers from responsibility for their decisions.

Kitzinger (2007, pg. 44) supports J.D. Miller's concept of the attentive public in her work on the role of media in public engagement. She presents the argument that "people are not passive consumers of media messages but bring their own interpretations to what they see and hear", supporting Wynne and Irwin's view of the public. She notes that "thinking about the role of the

3 John Dewey was an American educator. He published "The Supreme intellectual obligation" in Science Education 1934 in which he argued that young people should be inculcated with a 'scientific attitude' which would help them approach life in a rational and logical way.

mass media in 'public engagement with science' benefits from a reflective stance that includes an acknowledgement of these issues (pg. 48)."

Einsiedel (2008) sees the public not just as attentive but as active. She states that the public plays a vital role in the public communication of science and technology, a role that changes according to the issue at hand and is active, as "the public are constant producers and receptors of communication and information." Making reference to a 'participation explosion', Einsiedel presents the many avenues through which the public plays an active role in public engagement activities such as consensus conferences, citizen juries, scenario workshops and deliberative mapping, and outlines three elements that are essential to participation; access to information, participation in decision-making, and judicial redress when necessary.

The 'public' then is a heterogeneous group that varies according to time, place and issue and are 'products of context' (Einsiedel, 2008). While they may not possess a scientific background, citizens possess expertise gained by means of individual knowledge or perspective or by being attentive to particular issues, amassing an in-depth understanding of that issue. The public too is active, as both a producer and receptor of science communication. All of this suggests that a varied approach to science communication which carefully considers the public's understanding of science issues must be adopted in order to meet the many and diverse needs of this complex audience.

2.1.3: Understanding of Science and Technology—Measurement and Benefits

Scientific literacy is defined by Thomas and Durant (1987, pgs. 1-14) as, "to be scientifically literate is not to be expert in anything in particular but rather to be able to deal effectively with matters scientific as they arise in the course of life… it is to be able to recognize science for what it is, and thus be able to make discerning judgements about its personal and social relevance." They note that science has much to gain from wider public understanding of what it can contribute to "practical and cultural life," such as benefits to national economies, as highly qualified researchers and industrial workers are required for any country wishing to compete internationally, and that strength in science can improve a nation's power and influence. They caution however, that attaining these benefits "means convincing at least part of the non-scientific community in any society that the requisite technology is worth the investment." They note the benefit to individuals of understanding science and technology as science helps people makes sense of their everyday lives. This in turn raises two questions: how well does the public understand science and how important is civic scientific literacy?

J.D. Miller has over the last two decades conducted a considerable amount of research into levels of scientific literacy. He has carried out national surveys in the United States since 1979, amassing an empirical estimate of the proportion of American adults who qualify as being scientifically literate. His work (1992; 1998; 2000) has led to a more scientific and comprehensive understanding of the public understanding of science and technology. He states that the gauging of scientific literacy has moved away from early emphasis on the public regard for scientists to "a broader understanding of the system through which adults acquire scientific and technical understanding and the utilisation of that information in the formulation of science and technology policy in democratic societies (1992, pg. 25)." J.D. Miller (1998, pg. 205) states that "given the likelihood that science and technology policy will remain within the normal democratic policy formation process in most countries, it is important to develop usable measures of civic scientific literacy to better understand its origins and its function in modern democratic systems." He states that there can be little doubt that the levels measured in 1995 are too low in both the United States (12 percent in 1995) and the eleven European Union countries (5 percent on average).

Shamos (1995) separates scientific literacy into three levels. The first, *cultural* scientific literacy is the simplest of the three and represents the level of scientific literacy held by most educated adults; it is passive and enables the individual to read and understand a science-based newspaper article. The second, *functional* scientific literacy requires that the individual not only has a command of a scientific vocabulary but also that the individual be able to converse, read, and write coherently in a nontechnical but meaningful context. This level is more active; a functionally scientifically literate individual is not only able to read and understand a science-based newspaper article, but is also able to communicate the content of that article to another person.

The third level of scientific literacy, *true* scientific literacy, is described by Shamos as the most difficult to attain, as it involves knowing something about the scientific enterprise. Such an individual;

> "is aware of some of the major conceptual schemes that form the foundations of science, how they were arrived at, and why they are widely accepted, how science achieves order out of a random universe, and the role of experimentation in science. This individual also appreciates the elements of scientific investigation, the importance of proper questioning, of analytical and deductive reasoning, of logical thought processes, and of reliance upon objective evidence."

Shamos concedes that the third level is difficult and demanding to obtain, arguing that "true scientific literacy is likely to be out of reach for most members of society."

Doble (1995) examines the public's understanding of science and technology from a different perspective. He reports on results from a study conducted to examine the public's ability to understand complex scientific information which emphasises the importance of providing clear and correct information to the public. Doble's work, conducted in the US, weighs the public's capacity to participate in areas of science that are marked by complexity and uncertainty, particularly when the scientific community itself is divided. He presents public involvement in the scientific process as a case of "the impossible—thoughtful involvement by the general public—versus the inevitable—the public's insistence that it be included in the policy making process (pg. 96)." What Doble finds is that "the general public *has the ability and the willingness* to assess thoughtfully, even very scientifically, complex issues featured in areas of substantial expert uncertainty (pg. 99)." His results illustrate that the general public has the ability to rather quickly digest adequate technical information to make reasonable decisions about the most complex issues. He shows that public understanding of science and technology is achievable when the public is provided with the right information presented in the right way. "Ordinary Americans, not just the scientifically attentive or best informed, can engage in thoughtful deliberation about scientifically complex issues, and within a comparatively brief period of time, arrive at a reasonable judgement about what to do (pg. 116)." His work is important in that it highlights the fact that public misunderstanding of science stems not from an inability on the part of the public.

The plausibility of truly gauging a vast public's understanding of science is questioned by Peters (2000) and is discussed at length in the next section. For the purpose of this section, a snapshot of the type of measurement activity being conducted in the UK, US, Canada and the EU is useful to identify.

Results of previous measurement studies

Canadian efforts to develop public understanding of science have concentrated on the formal education system. The Pan-Canadian Education Indicators Programme (PCEIP) has carried out surveys every two years since 1999 which measure, among other indicators, adult scientific literacy. In 1995, it established a common framework of science education outcomes that set out to ensure "that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy" which it defines as "an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them."[4] The 2005 survey shows that across Canada, 71 percent of 13-year-olds and 64 percent of 16-year-olds reached the expected levels on the 2004 science assessment of the School Achievement Indicators Program (SAIP); that graduation rates for males remain higher in the physical, natural and applied sciences (though the gap narrowed between 1992 and 2001); and that in 2001, social and behavioural sciences and law are the fields of study with the most graduates in Canada.

Since 1973, European levels of scientific literacy are analysed regularly by the Eurobarometer, a series of surveys which are conducted to gauge public opinion on a number of issues throughout the member states of the European Union and are overseen by the European Commission. Results of the 2001 survey of EU candidate countries shows that "people do not only feel they are not well informed about science, but indeed, there is a surprising lack of fundamental scientific knowledge" [5] but that "most people agree that science is good and useful." EU Research Commissioner Philippe Busquin commented on the results stating that Europe "continues to have a positive perception of science, but we must address the concerns and scepticism that people express about some specific issues…. A clear challenge for all is to become more professional in the way science is communicated."[6] Busquin's comments show that a more diversified approach is emerging that will take into consideration the public's understanding of and attitudes toward particular issues in science rather than science as a whole.

Two special Eurobarometer surveys entitled 'Europeans, science and technology' and 'Values, science and technology' were published in June 2005. The main objective was to gather Europeans' general attitudes towards science and technology by analysing European citizens' interest in and knowledge of science and technology as well as their attitudes towards these domains. The studies cover the populations of the EU member states, of the then candidate countries (Bulgaria, Romania, Croatia and Turkey) and the three EFTA countries (Iceland, Norway and Switzerland) - a total of 570 million people. The results show a 'latent' interest among Europeans in science and technology and an implicit demand for more information. The authors note that "Europeans consider themselves poorly informed on issues concerning science and technology, and we can observe a link between low interest and the feeling of lack of information (pg. 125)." They also note that despite these findings, "progress has clearly been made since 2001 in terms of basic scientific knowledge. The 'science and society' action plan put into place by the European Commission in 2001 seems to have had a positive impact. However, the gap between science and society still exists (pg. 125)." They call for efforts to be made in order to bring science and technology closer to particular sectors of the public, namely

[4] See http://www.cmec.ca/science/framework/pages/english/table.html, last accessed April 16, 2010
[5] See http://ec.europa.eu/research/press/2001/pr0612en.html, last accessed June 2, 2010
[6] Ibid

"women, older people and those with low levels of education, who have a more sceptical perception of science and technology (pg. 125)."

Current levels of scientific knowledge in the EU, US, Japan and Canada are presented by Miller and Pardo (2008). Their results show that the level of public understanding of basic scientific concepts is 10 percent amongst US citizens and lower in the three other countries but that the level of public interest in new scientific discoveries is high in the US, EU and Canada.

Why, one might ask is the public's ability to understand science important? Thomas and Durant (1987, pg. 1-14) address this question by presenting a series benefits to society, organisations and individuals arguing that at least a moderate knowledge of science amongst the public can enable continued scientific research, help develop national economies by building a skilled workforce, ensure international competitiveness and allow individuals to gain a greater understanding of the benefits science can bring to their lives. Jon D. Miller (1998, pg. 203) also highlights the potential for increased participation in public policy disputes as a cause for seeking to increase the public's understanding of science.

Efforts to gauge the public's understanding of science over the past three decades have shown that scientific literacy remains low. Despite this, public support for science has not waned. This discrepancy between understanding and acceptance deserves to be addressed.

2.1.4: Does Understanding lead to Acceptance?

Having identified the public as a diverse and varied group influenced by context and individual perspective, and addressed various viewpoints on the importance of gauging civic scientific literacy, a further question arises from the examination of the results of some recent studies. Does public understanding of science lead to public acceptance of scientific endeavour? Varying views of the meaning of understanding have been presented; some equate understanding with knowledge (Hirsch, 1987; Hazen and Trefil, 1993) while others equate it with appreciation (Lederman, 1993). These incongruent meanings may have led to a misunderstanding of the relationship between understanding and appreciation.

Evans and Durant (1995) argue that there is not a consistently positive relationship between knowledge and attitudes, arguing, as Einsiedel would, that the public's perception of science and technology is shaped in large part by the context in which a given science issue is presented. Their work, resulting from a survey of more than 2,000 British citizens, examines the relationship between understanding of science and support for science, and sets distinct measures for both knowledge and attitude. Their measurement of knowledge contains two dimensions; understanding of the scientific product and understanding of the scientific process. They define scientific product as the "elementary theoretical and factual findings of science" while scientific process is defined as the "elementary nature of science as a knowledge producing activity (pg. 58-59)." Attitude then is defined as "an opinion that indicates more or less support for, or a more or less positive evaluation of, science, scientists and scientific activities (pg. 59)." Overall, Evans and Durant show that there is a *vague* relationship between knowledge and attitudes with regard to 'non-useful research' and a significant *negative* association with morally contentious research. This illustrates that the impact of knowledge on attitude varies according to the particular science issues under consideration. More importantly however, it shows that *interest* in science may well be a stronger predictor of attitudes than is scientific *understanding*. Evans and Durant conclude that "although an informed public opinion is likely to provide a slightly more supportive popular basis for some areas of scientific research, it could serve to constrain research in controversial areas (pg. 57)." Their findings lie in favour of the promotion of the public understanding of science, for as they state there are "many legitimate motives" for doing so (pg. 71). They do however warn practitioners to proceed with caution, particularly in areas of contentious science. Adherence to Irwin's (2008) call for open and honest communication of scientific issues where risk is involved and Jackson et al.'s (2005) call for upstream engagement are two means of dealing with the issues Evans and Durant forecast.

Peters (2000) examines the relationship between understanding of science and attitudes toward science in detail. Presenting the long held hypothesis that "pessimistic risk judgements, which lead to fears or so-called *acceptance problems* of modern technologies are caused by insufficient knowledge about the sources of risk and their impacts (pg. 265)", he accepts that the hypothesis has some validity in that emerging technologies and environmental issues are inherently complex and difficult to understand, but argues that this is too simplistic an approach. Analysing the 1992 Eurobarometer 38.1 survey on the public understanding of and attitudes toward science and technology, Peters argues that the survey is based on two assumptions that typify a technocratic approach. One assumption is that risk perception and attitude formation are decisively influenced by scientific and technological knowledge, while the second is that the most significant difference between lay people and experts with respect to the evaluation of technologies is the amount and quality of factual information available to inform opinions. In making these assumptions, he argues, the survey implicitly presumes a *positive* relationship exists between knowledge and attitudes. Peters argues that this presumption is in fact weakly and inconsistently supported by the survey results. He states that while understanding of science and technology requires a basic knowledge of scientific facts and an understanding of the scientific process, the survey's approach leaves out the fact that social and political knowledge is important in understanding how science and technology sit within society. This argument is in agreement with Wynne and Irwin's (1995) theory of individual knowledge and Einsiedel's (2000) work on contexts. Peters presents empirical data from two studies (Hennen and Peters, 1990; Wiedemann et al., 1991) to illustrate that there is no universal relationship between knowledge level and attitude. He argues that the relationship that does exist seems to depend on a number of factors particular to the respective technology or technological project, and that in the case of controversial or complex issues, the relationship may be the opposite of that so long hypothesised.

Scheufele (2007) takes a similar stance, arguing that knowledge is in fact marginal in the shaping of public attitudes toward science and technology. His 'knowledge deficit versus low information rationality' theory examines ways in which the public forms opinions about scientific issues. He puts forth the concept of 'cognitive misers' stating that most people learn by drawing upon a minimum amount of information, minimising the economic costs of making decisions and forming attitudes by collecting only as much information as they think is necessary to make a decision. Essential to attitude formation resulting from an intake of information is the way in which an issue is 'framed' (the context in which an issue is communicated and made to fit into a person's pre-existing knowledge). As Scheufele points out, research has suggested that the way the popular media present an issue, along with people's value systems and predispositions, plays a much greater role in shaping citizens' attitudes toward new technologies than understanding scientific facts and processes. He asserts that attitude formation, ultimately, is a "competition between frames of public discourse – offered by interest groups, policy makers and mass media – and the value systems and predispositions of citizens (pg. 23)."

Bauer (2008) too supports this concept. He analyses the commercialisation of science and the effect of product marketing and public relations on the communication of science to the public. His analysis shows that literacy and scientific ideology are *negatively* correlated in most countries, and that in countries with high levels of scientific productivity, the more likely it is that knowledgeable citizens will reject certain scientific ideologies. "The 'deficit concept' of public understanding of science is falsified," he states, "the more we know the science, the less we love it (pg. 21)." But this he says should not be viewed as a problem to be solved, for a blend of public scepticism and scientific productivity is in fact desirable, as a sceptical public will not be awestruck by new scientific developments, leading to a more empowered public that is able to recognize exaggerated claims while maintaining valuable productivity. By Bauer's definition, a mature science culture should combine "high literacy with sceptical but utilitarian attitudes, and a moderate level of interest (pg. 22-23)."

Schiele (2008, pg. 114) is in agreement with this assertion, noting that an intelligent public can be knowledgeable of science and still question. He emphasises the fact that "the public is ambivalent. It doesn't necessarily run counter to science or scientists. It is neither reactionary nor obscurant. It simply considers that scientific progress does not necessarily mean enhanced well-being and better quality of life."

In analysing the importance of the public's understanding of science, the relationship between knowledge and appreciation is critical. The literature shows that intense scrutiny of public understanding has perhaps skewed attention away from the more important matter of public interest in science. In acknowledging the role that public interest plays in garnering support for and appreciation of science, the importance of the social and political knowledge of the public is made clear. The way in which science is framed then, is important to consider, particularly with regard to emerging science where public scepticism is likely. It is worth noting however that a degree of scepticism can play a positive role in increasing interest and need not be seen as damaging to public trust.

2.1.5: Trust in science

An inherent determinant of public attitudes toward science, and a key indicator used in studies to measure the public acceptance of science is trust. The public level of trust in scientists has long been measured in both the United States and the UK, with results initially high as scientists were well regarded and viewed as experts. As ambivalence has increased in recent years however, a closer examination of the relationship between approaches to science communication and its impact on trust has begun.

The issue of how scientific information is communicated to the public and its impact on trust in the scientific community is illustrated by Wynne (1989), a case study that illustrates the danger of withholding information from a concerned public and understating uncertainty. He examines the situation sheep farmers in Cumbria, UK, found themselves in months after the disaster at Chernobyl led to the irradiation of their sheep and a total ban on selling. Wynne examines the manner in which the farmers where kept informed of developments, the behaviour of the 'experts' and the general outcome of the way in which the situation was handled.

As Wynne states, "issues of intense risk and uncertainty place scientists and government officials in the compromising position of attempting to rationalize real and considerable effects that are too often based on abstract scientific justifications (pg. 11)." Central to success in this aim is the perceived credibility of scientists amongst the public, which directly influences the effectiveness of communicating complex information to lay citizens. In the case of the Cumbrian farmers, the 'experts' (scientists, the Ministry of Agriculture, Fisheries and Food or (MAFF) and the Department of the Environment) had a distinct lack of credibility with the farmers, brought on in part Wynne argues, by an assumption on the part of the experts that scientific knowledge could be transmitted unaltered to local circumstances. He states that scientific knowledge is always integrated with "supplementary assumptions that render it culture-bound and parochial... [and that] efforts to communicate [knowledge] that ignore this fuller social dimension are likely to be ineffectual or even counterproductive (pg. 12)." Effective communication requires a restructuring of social relationships, something that did not occur in Cumbria. A second impediment to the credibility of the scientists was their assumption that the farmers were not capable of handling the scientific facts surrounding uncertainty and risk and needed to have technical information simplified, leading to Wynne's criticism of this 'deficit model' of communication. In understating the uncertainty of the situation, the experts damaged the credibility of scientific information by failing to create an 'intercultural understanding'.

Furthering the argument that uncertainty must not be understated if trust is to be maintained, Shapin (1992) calls for a 'warts and all' approach to science communication. He argues that traditional public communication activities which seek to provide the public with scientific knowledge are undoubtedly important, and that the scientific community should commit itself to share knowledge openly, leaving nothing out. The public, he feels, have a desire not simply to understand the science, but the role of the scientists and the way in which science is created. He calls for scientists to share the processes by which they come to know what they do, as the public's thoughts on the potential of risk in scientific research will be shaped by their appreciation of the process by which science is made. Trust in the process, he says, can be achieved by telling people what science is like "in the making (pg. 28)." What he argues firmly against is hiding or concealing science for fear it will not stand up to informed public scrutiny, and that communication aimed at growing the public understanding of science needs to present a complete picture of the process of knowledge-making. Jackson et al. further this argument in their work on upstream engagement, discussed later in this chapter.

Doble (1995) in is agreement with Shapin, stating that trust can only be achieved with total and complete openness between the lay public and the scientific community. He notes that this is especially true when dealing with areas of science that are inherently uncertain or complex. He negates the practice within the scientific community to remain quiet when uncertainty arises in case that uncertainty amongst scientists will lead to public mistrust of the science. Instead he argues that uncertainty among experts need not close channels of communication because the public does not demand a standard of 'zero risk'. He states that the public is in fact capable of understanding complex and demanding issues with relative speed and accuracy and that "the public debate need not be paralysed by scientific uncertainty (pg. 114)."

Like Doble and Shapin, Valenti and Wilkins (1995) argue that risk communication must be a dialogue between all parties concerned, with the public being provided with all information necessary to engage in said dialogue which should aim to "persuade the targeted public to consider provided information, not to compel people to believe and then act on a particular 'truth' (pg. 177-194)." The argument in favour of open information sharing and the value of public's perspective when dealing with risk communication is evidenced by Jasanoff (1997). She argues that "lay questioning, however ignorant or ill-founded, might have led to deeper reflection on the limits of expert knowledge and, in turn, to more collaboration among citizens, scientists and government about how to manage multiple uncertainties (pg. 227)" in the case of the 1996 UK BSE crisis.

In marked disagreement Durodié (2004) argues that "we should not include 'lay values' or 'local knowledge' into science, peer review or anywhere else, as there is no such thing. These are in fact mere opinions that need to be interrogated just as much as the scientific evidence itself (pg. 89)."

Wilsdon and Willis (2004) present the concept of moving public engagement 'upstream' in their report for DEMOS, in complete contrast to Durodié's position. They present upstream engagement as enabling public debate to take place "at a stage when it can inform key decisions about their development and before deeply entrenched or polarised positions appear (pg. 19)." They argue that the assumptions, values and visions that drive science must be exposed to public scrutiny and that "those whose engagement is being sought need to know that their participation will affect the policies and processes under discussion. They want assurance that trajectories of change and innovation will take meaningful account of their views (pg. 16)." Wilsdon and Willis see the upstream approach to science communication as having a direct impact on public trust as it enables public participation in science to be substantive. This they state will allow the public not just to 'inform decisions' but to 'shape them.'

Wynne (2006) notes that the 1996 UK BSE crisis was not, as some believe, the root of public mistrust of science and scientists, and criticises the idea put forth by supporters of the dialogue model, that "mutual education, including the scientific community learning from its encounters with publics, will be the means of regenerating a failing public trust (pg. 213)." Instead he reiterates his earlier argument that public mistrust might not result from public misunderstanding of science but from resentment on the part of the public at having its concerns dismissed by the scientific and policy institutions in charge. He notes that this idea has not however been recognised by policy makers, for scientific policy is continuing to be developed according to the cognitive deficit model. As he puts it, "public mistrust is not due to the fact that science shows uncertainty… its appears to be due to public awareness of unpredicted future consequences which the scientific institutions effectively deny by referring only to risk assessment as an attempted means of public reassurance (pg. 216)."

Irwin (2008) calls for a tell-all approach to science communication that presents the science intact, complete with uncertainty and reflects the scientific process, as described by the Chief Scientific Advisor in the 2000 Lords Report who he quotes as having stated "the full messy process whereby scientific understanding is arrived at with all its problems has to be spilled out in the open (pg. 202)." In this way, Irwin states "a 'culture of trust' rather than one of secrecy can be developed (pg. 202)". He draws attention to several points that have become central to the language of scientific governance in the UK, the Netherlands and Demark in the wake of the BSE crisis;

- 'Trust can only be generated by openness'
- 'Openness requires recognition of uncertainty, where it exists'
- 'The public should be trusted to respond rationally to openness'
- 'Scientific investigation of risk should be open and transparent'
- 'The advice and reasoning of advisory committees should be made public' (Phillips et al., 2000)

Emerging from the literature then is the importance of dealing openly with the public, particularly where issues of uncertainty arise. Of critical importance in maintaining public trust in the scientific community is the acknowledgement of the public's knowledge and perspective on issues and the provision of opportunities for all parties involved to form a dialogue surrounding areas of concern. By doing so, the scientific community will demonstrate respect for public opinion and enable participation thus earning the trust of the public.

2.1.6: Models of Science Communication

Publication of the 2000 House of Lord's report and the EU's 'Science & Society' action plan saw a call for science communication practitioners to alter their approach; to replace the deficit model with a more interactive dialogue model based on the assumption that the deficit model and the PUS approach had failed. As more in-depth definitions of the public have emerged, along with a broader view of the level of public understanding of science and its impact on public attitudes toward science, this 'failure' has been redressed. By the late 1990s, alternatives to the dominant deficit model of science communication were being proposed, leading to the development of a range of potential models for science communication.

Gregory and Miller (1998) argue that the deficit model receives much criticism because of its association with the PUS movement of the 1980s. In their view, the deficit model's fundamental error was its misunderstanding of the public which did not take into account "how the information [the public] receives will interact with their pre-existing knowledge and attitudes and ignor[ed] any demands they may have for what they learn to be relevant to their individual situations (pg. 97)." What is needed according to Gregory and Miller is a 'contextual approach' to science communication, which calls for scientific information to be given to the public in ways that relate to their specific interests and concerns. While they acknowledge that this approach makes greater demands of the scientists, they note that it will allow scientists and the public "to work together as citizens of a scientific culture (pg. 99)."

Einsiedel and Thorne (1999) state that two categories of factors, individual and social-structural, shape public perceptions of scientific uncertainty and subsequent coping strategies. Individual factors include elements such as personal skill levels, social activity and general and specific motivations, while social-structural factors relate to issues of externally controlled access to information. They present two models of science communication, the *scientific literacy* model and the *interactive science* model. The scientific literacy model contends that knowledge of basic scientific ideas and concepts is required for people to function well in a variety of cultural contexts. This model, they argue, rationalises the call for raising public awareness and understanding of science as its places value in civic scientific literacy and can also be labelled the cognitive deficit model. The Interactive science model on the other hand, assumes that there are uncertainties embedded in the science and technology and argues that these uncertainties cannot be separated from their social and institutional connections. Like Doble, Einsiedel and Thorne recognise the public's ability to understand complex scientific issues, and like Kitzinger, they acknowledge the public's preconceptions of science as attained through their personal experience. They also note the danger of viewing the public as a homogenous audience, stating that the public has different degrees of knowledge and uncertainty, necessitating a flexible approach to information provision. While they acknowledge strengths and weaknesses in both models, they ultimately call for an *integration* of the scientific literacy and the interactive science models which they argue could result in "a more fertile approach to understanding publics and their approaches to scientific uncertainty (pg. 52)."

S. Miller (2001) points out that the end of the deficit model is not the same as saying there is no longer a deficit, noting that scientists and the public are not on equal footing and that scientists deserve respect for their work. He urges a continuation of existing trends; that scientists should still be given training in dealing with the media, and that funding should be given to enable scientists to take part in PUS activities. What needs to be addressed, he argues, is the reasoning behind these approaches and a greater understanding of the public, for "where science is being communicated, communicators need to be much more aware of the nature and existing knowledge of the intended audience. They need to know why the facts being communicated are required by the listeners, what their implications may be for the people on the receiving end, what the receivers might feel about the way those facts are gleaned, and where future research might lead (pg. 118)."

Durodié (2004) outlines what he sees as the limitations of public dialogue in science. He argues that public participation in science is problematic because it;

> 1) Demoralises students by "effectively fetish[ing] information and opinion over evidence and explanation." He feels that this approach "limits and constrains the dynamism of science, further facilitating the demise in its popularity (pg. 84)." He supports this with an example from the GM food debate in the UK arguing that once public dialogue was brought into the debate, scientists were no more hesitant than before about GM itself, they had just become more hesitant about saying so.
>
> 2) Patronises the public "by having to make science more 'accessible' in order to be 'inclusive', this ends up by diluting the detail, eroding the evidence and trivialising the theory. This is not access to science but access to science as simplistic morality tales for a nervous society (pg. 85)."
>
> 3) Elevates new 'experts' by "flatter[ing] those who claim to represent the public or truly know what public opinion demands (pg. 86)."
>
> 4) Deflects blame "from those whom we ought to hold to account and, far from making matters more transparent, it ends up by further politicising the decision-making process (pg. 88)."

He states that "we should move away from our growing obsession with the impact of science upon society and begin to examine a bit more critically the impact of society upon science (pg. 90)."

In response to Durodié, Jackson et al. (2005) seek to clarify what is meant by dialogue emphasizing the importance of engagement, particularly at the upstream stage of research. They state that a dialogical approach does not remove the authority or expertise from science, as Durodié fears it would, but that instead, "it locates scientific developments in a wider social context and enables the inclusion of a wider range of relevant expertise with regard to the implications of such developments (pg. 350)." It is overall an "open exchange and sharing of knowledge, ideas, values, attitudes and beliefs between stakeholders, scientists, publics and decision makers (pg. 350)." While Durodié states that public debate and scientific debate should remain separate, Jackson et al. feel the two should be coupled lest a dislocation of scientists from the public interests unfold.

They highlight three key purposes for engagement;

1. increased democracy by promoting open and transparent decision making
2. greater trust and confidence in the regulation of science and decisions taken
3. better decision making (pg. 352).

Wynne (2006) analyses recent efforts to 'restore' public trust in science, which he sees as adopting an explicitly two-way approach to public communication of science and technology, leading many to feel that a shift has taken place away from the 'old' one-way approach. He states that "...early 'public deficit model' explanations of why scientific assertions about the acceptability of a given technology were suffering public rejection were based upon the public's supposed misunderstanding of the cognitive contents of scientific knowledge (pg. 215)." The reason behind this seeming shift, he argues is a widely held belief that public trust has been fading as a result of failure of the old approach to mitigate the problem. This argument is misleading, he states, as it relies upon an ability to mark out events or conditions that have led to this seemingly rapid change in public attitude. In fact, Wynne puts forth, no such dramatic change may have actually occurred and questions whether "overt abandonment of the deficit model has been more apparent than real (pg. 213)".

Trench (2008b) too questions the claim that there has been a large-scale shift from a 'deficit model' of communication to a 'dialogue model', referring to the commonly held idea that there was been a shift from one model to another as the 'grand narrative' of public communication of science and technology. He argues that it is unlikely that the diverse scientific community could have adopted a new approach to communication over a short period of time and notes that the supposed shift was all too neatly tied in to the change of millennium, presented as the 'mood for dialogue' in the 2000 House of Lord's report. What is more likely, he states, is that a number of different approaches, methods or models are being used simultaneously, noting that the deficit model remains the common choice of practitioners, citing Trench and Junker (2001). He notes that this narrative may well be valuable in shedding light on the "limits of one approach and possibilities of another" and cites Sturgis and Allum (2005) who state that while criticisms of the deficit model are largely 'invalid', they "do not sufficiently problematise the deficit model to justify scrapping it altogether." Overall Trench highlights the following three points;

1. The deficit model survives as the effective underpinning of much science communication

2. A legitimate case can be made for retention of a dissemination model (of which the deficit model is a variant) in certain circumstances
3. Dialogue refers to multiple options that span a considerable breadth of spectrum.

Drawing on models of science communication found in the literature (Research International, 2000; Trench and Junker, 2001; Lewenstein, 2005) he has constructed the following analytical framework of science communication models that "presents a grid centred on a triad of models":

Base Communication models	**Ideological and philosophical associations**	**Dominant models in PCST**	**Variants on dominant PCST models**	**Science's orientation to public**
Dissemination	Scientism Technocracy	**Deficit**	Defence Marketing	They are hostile They are ignorant They can be persuaded
Dialogue	Pragmatism Constructivism	**Dialogue**	Context Consultation Engagement	We see their diverse needs We find out their views They talk back They take on the issue
Conversation	Participatory democracy Relativism	**Participation**	Deliberation Critique	They and we shape the issue They and we set the agenda They and we negotiate meanings

Noting that "characterising the dominant models… in this way is not to propose a hierarchy, or an evolution", he forecasts that all three models will "continue to have their specific applications in particular circumstances."

Not in disagreement with Trench, Irwin (2008) introduces the concept of first and second-order approaches to risk communication. He argues that in certain contexts, a transition has taken place from 'first-order' or deficit models of science-public relations to a greater emphasis on public engagement and dialogue, what he terms 'second-order' thinking. Like Wynne and Trench, he does not believe that there has been a movement from one model to the next, but that "the situation in most national and local contexts is of these different orders being mixed up (or churned) together. The deficit model coexists with talk of dialogue and engagement (pg. 199)." He sees the 2000 Lords Report as having emphasised a 'new mood for dialogue' over science and technology and the subsequent EU action plan, that called for 'open dialogue' and a 'new partnership', as indicative of a change that is taking place that calls for more open, active and democratic relations between science and citizens. While Irwin agrees this is both desirable and necessary, like Wynne he sees the impetus of movement from deficit to dialogue as based on the ill-conceived idea that "difficulties in the relationship between science and society are due entirely to ignorance on the part of the public and that 'with enough public-understanding activity, the public can be brought to greater knowledge, whereupon all will be well'" (pg.201), a comment made by the Chief Scientific Advisor in the 2000 Lords Report. Irwin states that this misconception of an ignorant and uninformed public has provoked the call to change from deficit to dialogue, and because it has been based on a misconception, dismisses the need for an all out change. He sees the reality not as a shift from one model to another, but as uneasy coexistence of the two. What is required he suggests is 'third-order' thinking, a similar notion to Evans and Durant (1995), which would eliminate the concept of a right/wrong or superior/inferior approach to communication and would instead emphasise the importance of contextual judgement while recognising the limitations and strengths of all approaches.

Van der Sanden et al. (2008) would concur with the concept of a continuum, as they argue that any one model of science communication cannot be applied without consideration of the unique properties of the field under consideration. They state that all distinct 'targets, modalities and instruments' must be investigated and validated on their own merits, according to the particular field of science communication. Noting that dialogue is "just a technique, a method that can be used in any modality of science communication to serve any of its goals (pg. 89)", they see two-way communication built on dialogue, allowing for negotiation from science and towards science, as the way to achieve 'modern' science communication. Dialogue, they argue, is not concerned with public understanding or the 'classical' goals of science communication but is a useful tool for allowing scientists and the public to get to know one another. While not ruling out the use of a one-way model for the purpose of growing the public's understanding of science and technology, Van der Sanden et al. maintain that "dialogue is not about winning or convincing, but about informing the other or oneself about facts, concepts, notions, feelings, emotions and fears [and that it is] appropriate to restrict dialogue exclusively to the public awareness of science (pg. 91)."

Publication of the 2000 House of Lord's report caused a stir in calling for increased use of a dialogue model, leading many to conclude that the deficit model needed to be replaced. Dialogue however, has also been questioned leading to the emergence of yet another label, engagement. The fact is however, the deficit hasn't gone anywhere as scientists and the public are not yet on the same footing and many public engagement activities still rely on the old deficit approach. It is a blend of models then that is needed, with each particular circumstance considered to identify the most effective and appropriate model to be used.

2.1.8: Conclusion

A complex understanding of the public has emerged that recognises it to be a heterogeneous group, strongly influenced by context and varying by time, place and issue (Einsiedel, 2000; Irwin and Michael, 2003). A given public's social and political knowledge is as important to consider as its scientific knowledge, for as Wynne and Irwin attest, all three factors combine to determine the response one will have to scientific research, particularly where emerging science and technologies are concerned. As both producer and receptor of science communication, the role of the public is critical to the impact of public engagement activities and as such a varied approach which carefully considers context is essential to meeting the many and diverse needs of this complex audience (Einsiedel, 2008). Central too is an understanding of the importance of the public's understanding of science and its relationship to public acceptance of science.

Both science and society stand to benefit from a strong foundation of civic scientific literacy (J.D. Miller, 1992; 1998; 2000). If scientific endeavour is to be sustained, society must continue to produce new generations of scientists and the needs of society in large part shape scientific research agendas. Society on the other hand benefits considerably from research outcomes, relying on science to produce technological developments and to provide solutions to biological, physical and societal problems. But while public understanding is important, it is not essential to public interest in and support for science as one can exist without the other (Evans and Durant, 1995; Peters, 2000; Sheufele, 2007). In this regard, the complexities of the public as mentioned above take on a new dimension. The public can fail to understand the theoretical concepts and principles behind a particular area of science and be sceptical of the outcomes or even safety of the research in question while still expressing support for science and the scientists involved in research (Bauer, 2008; Schiele, 2008).

Essential to the public's acceptance of scientific research and its findings is trust—in both the scientists involved and the public policy which influences science decision making. In order for trust in science to be maintained, it seems clear that open and early information sharing must be carried out (Wynne, 1989; Shapin, 1992; Doble, 1995). This, along with recognition of and respect for the public's socially and politically constructed knowledge and individual perspective will combine to form a healthy relationship between science and society (Wynne, 1995; Irwin, 2007). Public engagement activities which take all of the above into consideration are the way forward. This can be best achieved through approaches to communication which blend dissemination, dialogue and engagement to form a model unique to each context (Trench, 2008; Irwin, 2008).

The ability to transpose this approach to the medium of the Web is a principal interest of this study. In the chapters to follow, use of the Web as a medium for communication and the ways it has developed over time will be presented, along with an overview of the science communication on the Web to date.

2.2: Web Communication

2.2.1: Introduction

Not long after its inception the World Wide Web was being hailed as having "revolutionized computers and communications like nothing before. [It had become] a worldwide broadcasting capability, a mechanism for information dissemination, and a medium for collaboration and interaction between individuals and their computers without regard for geographic location" (Leiner et al., 1997, pg. 102). In the mid-nineties, the number of websites registered with a domain name and content was one million. Within a decade that number had reached one hundred million and continues to rise.[7] In the years since Tim Berners-Lee developed the World Wide Web, there has been a huge increase in the number of people accessing the Internet and in the amount of information available online.

This chapter will outline major developments in the evolution of the Web from its conception through to the rise of 'Web 2.0' technologies, illustrating the growth of possibilities available to biomedical science research institutes for the dissemination of information to the public. A number of studies will be examined to evaluate the efficacy of the Web as a communications tool by addressing the importance of the following attributes; credibility; usability; interactivity; content; design; and accessibility. Finally, the capacity for online public engagement offered by the Web will be addressed.

2.2.2: Evolution of the Web as a Communication Medium

The earliest incarnation of the Internet was accessible only to the academic, military and government groups that were involved in its conception. "Use of the Internet for exchange of scientific data was characterised by exclusivity during its pioneer era" (Minol et al., 2007, pg. 1129). Tim Berners-Lee, while consulting for CERN, would write a notebook program, 'Enquire-Within-Upon-Everything', which allowed the first links to be made between arbitrary nodes, leading to the creation of the Hypertext Transfer Protocol (HTTP) that gave us the World Wide Web, a platform for mass communication. From the early nineties onward, "[i]n combination with easily operable software from Netscape, the additional protocols and extensions developed by Tim Berners-Lee paved the way for the Web to become a channel of mass communication." (Minol et al., 2007, pg. 1129). As Berners-Lee (1996) states, "the goal of the

[7] From: *http://www.zakon.org/robert/internet/timeline/*, *http://news.netcraft.com/archives/2006/11/01/november_2006_web_server_survey.html*, last accessed January 5, 2010

Web was to be a shared information space through which people (and machines) could communicate. The intent was that this space should span from a private to a public information system (pg. 1)."

'Read only' Web is a term that refers to early years of the Web's development (Minol et al., 2007). While the Web in this period underwent considerable growth, with the number of Web pages rising from 1.3 million in 1995 to more than 1 billion by January 2000 (Peterson, 2001); Web content however, was presented in pages made up almost entirely of text (Picardi & Regina, 2008). Of particular importance in this era of the Web's development was the ability to access information and find information online; use of the Web was concentrated on the acquisition of information.

Recent Web technology developments present new opportunities for enhanced online participation leading to the emergence of the 'Read-Write' Web (Minol et al., 2007). The Web is now frequently used by a broad spectrum of users in the exchange of information, for dialogue and in the accumulation of knowledge. With the increasing sophistication of Web technologies, a new era of collaborative co-creation has begun, with the Web shifting to a user-driven platform. User-driven technologies have changed the Web from merely a storage space for information to a global system for the processing of data, i.e. a platform. The Web is being transformed from a tool of distribution to a tool of genuine communication" (Minol et al., 2007, pg. 104).

'Web 2.0' is a term that emerged following an O'Reilly Media Web 2.0 conference in 2004 that has become widely used to describe Web applications which allow for interactive information sharing. An inherent quality of 'Web 2.0' applications is that the user is placed in the role of creator and can change or add content. Some of the more common user-driven applications include social networking sites such as Facebook and MySpace, video sharing sites such as YouTube, along with wikis and blogs. While often viewed as a new form of the Web, Berners-Lee negates this assertion, stating that interactivity via the Web is not a new phenomenon but that the Web "was designed to be as a collaborative space where people can interact."[8]

Rise of Internet Use

In the mid nineties, it was estimated that around 200 million computers on the planet were capable of being interconnected and of being used to send email (Rzepa, 1999). The total

[8] developerWorks Interviews: Tim Berners-Lee http://www.ibm.com/developerworks/podcast/dwi/cm-int082206txt.html, last accessed January 5, 2010

number of Internet users in the world as of 30 September 2009 was nearing 2 billion.[9] That figure can be seen below, broken down into world regions.

World Regions	Internet Users Dec. 31, 2000	Internet Users Latest Data	Penetration (% Population)
Africa	4,514,400	**67,371,700**	6.8 %
Asia	114,304,000	**738,257,230**	19.4 %
Europe	105,096,093	**418,029,796**	52.0 %
Middle East	3,284,800	**57,425,046**	28.3 %
North America	108,096,800	**252,908,000**	74.2 %
Latin America/Caribbean	18,068,919	**179,031,479**	30.5 %
Oceania / Australia	7,620,480	**20,970,490**	60.4 %
WORLD TOTAL	360,985,492	**1,733,993,741**	**25.6 %**

Table 2.2.1 : *World Internet Usage and Population Statistics.*[10]

Not only has the number of Internet users increased dramatically in the last decade, the *way* the Web is used has also changed. "Today the net is ever more populated by active web users who manage blogs, exchange files, put videos online, and produce podcasts: in short, the audience stands up and enters the stage" (Picardi & Regina, 2008, pg. 1). Changes to the Web platform will continue as technology develops and user motivation shifts. With these developments, new means of communicating information to a range of audiences will continue to emerge.

2.2.3 Evaluating the Efficacy of websites through specific attributes

Alongside development of the Web from an information resource to a platform for interactive user-driven information creation and a steady, dramatic rise in users, research has been conducted to evaluate the efficacy of the Web as a means of communication and to identify those attributes inherent to successful website development. As with other new forms of media before it, the capacity of the Web as a tool for learning has been explored by examining those attributes that are crucial to a website in order to yield a positive user experience. These include the impact of perceived credibility of a site on user experience, the importance of content and usability features to user satisfaction, the role of design 'look and feel' on user experience and the impact of a site's accessibility features.

[9] http://www.internetworldstats.com/stats.htm, last accessed January 5, 2010
[10] Ibid.

Credibility

Due to the open nature of the Web, the issue of ensuring and preserving website credibility demands careful consideration. Website credibility refers to the reputation of the website for providing factual information; it is a measure of the extent to which users can believe the content they find on the website. When it comes to institutes publishing content online, identification of the institute publishing the site and attribution of authorship which illustrates the publisher's expertise in the content area should be clearly stated (Peterson, 2001, pg. 250-251) as institutional reputation provides the credibility for content posted online. A number of studies have highlighted the importance of other elements in the pursuit of perceived credibility.

In his examination of perceived website credibility, Fogg (2002) identifies design 'look and feel' as critical to the users' acceptance of information presented online. The study considers the response of more than 2,500 people to the credibility of two live websites about similar topics, gathering comments to find out what features of a website get noticed when users are asked to evaluate credibility. The study showed that the design of a website has the most significant impact upon a users' perception of that sites credibility. Websites that used an appealing lay out and made effective use of colour and font were deemed to be more credible that those which were not.

Triese et al. (2003) identify the impact of domain name as a principal determinant of website credibility. They show that "audiences use source credibility as a cue to the quality and veracity of messages (pg. 310)" and that the "two most important dimensions of credibility are trustworthiness and expertise (pg. 311)."

Flanagin and Metzger (2007) analyse perceived credibility of Web-based information by examining the role of site features finding that the impact of familiarity with the website's sponsor is one of, but not the most critical, features of significance in determining a website's credibility. They find that credibility assessments appear to be primarily due to website attributes such as design features, but also find that depth of content and site complexity are important factors.

Usability

Essential to an effective website, due to its direct relationship to user satisfaction, is ease of navigation through pages. This is all the more important in sites that make extensive use of interactive features that see users following non linear paths through site content. As noted by

Krug (2000), "clear organisation structure with an easy-to-use navigation system is essential. Navigation is defined as the user's ability to find information efficiently with few barriers. If users cannot figure out the nature or structure of the site and what they find there, they become frustrated and quickly leave. Good navigation makes users more likely to return to the site."

Palmer (2002) notes that "good navigation aids let users acquire the information they are seeking quickly and efficiently. Windows, menus, dialog boxes, and control panels however, can either aid or impede the process of moving through a website (pg. 102)." He emphasises the importance of graphical layout in navigation, noting that "buttons, bars, and other aids should be grouped together and placed consistently (pg. 103)" illustrating the close relationship between navigation and design.

Whitten et al. (2008) illustrate critical factors in attracting and maintaining users in a study which examined how breast cancer websites employ basic use and design tenets in order to effectively reach target audiences. They note that usability has been shown to influence user satisfaction, user traffic, whether or not users return to a site, error reduction, and accuracy issues.

Interactivity

Interactivity has been defined by Steuer (1992, pg. 84) as the "extent to which users can participate in modifying the form and content of a mediated environment in real time." It can, when well executed, improve performance quality leading to increased user satisfaction. The potential for interactivity makes the web "a dynamic medium for influencing learning, attitude change and behaviour." (Stout et al., 2001, pg. 721).

Tremayne and Dunwoody (2001) examine the impact of interactivity on the presentation of science news on the Web. They present a model of interactive information processing that suggests a relationship between interactivity, cognitive elaboration and learning. In a study conducted to test the model, they show that more complex websites with a high use of hyperlinking results in greater sender-receiver interaction. Web users, they note "by following links, using search engines and selecting items from pull-down menus, have the capacity to take a more active role in information consumption" and that advances in Web software is increasing the possibilities for "user[s] and a site to collectively construct meaning (pg. 111)."

Teo et al. (2003) investigate the effects of interactivity level on Web users' attitude towards commercial websites. They show that "increased levels of interactivity on a website have positive effects on users' perceived satisfaction, effectiveness, efficiency, value and overall attitudes towards a website (pg. 281)."

Interactivity allows for the enhancement of content to improve user experience by placing greater control in the hands of the user. User-driven applications such as blogging, social bookmarking, and tag clouds can enhance user experience considerably and lead to the formation of online communities built around a given website.

Content

Of critical importance to an effective website is content. According to Williams et al. (2002) website content should be accurate, current and evidence based, listing the sources used and attributing the author. Information should be presented with lack of bias and contain breadth and depth either within the site or by including hyperlinks to relevant external sites. User satisfaction is strongly influenced by the ability to find information of substance. The old standard of websites as a business card model, providing general institute information and little else, is being challenged by sites with in-depth information on the institute's research and findings as observed by Trench (2008a) who notes the presence of websites which "facilitate public access to previously private spaces."

In Coleman et al.'s (2008) study of user engagement and usability, they find that "two of the site features that are under control of website creators—story content and site appearance—showed strong correlations between users' satisfaction and more positive attitudes… [but that] story content mattered most (pg. 194)."

Design

The design or aesthetic quality of a website may seem a trivial consideration; however Fogg et al.'s (2002) credibility study shows that the 'design look' of a site is the single most important determining factor identified by users. By 'design look' users refer to the overall visual design of a site including layout, typography, font size and colour scheme. Nearly half of users note the design and look of the site in their comments. The second most common feature noted pertains to information structure and information focus. It is interesting to note that "the data shows that the average consumer pays far more attention to the superficial aspects of a site, such as visual cues, than to its content (pg. 6)." The study illustrates the importance to users of a well designed and visually appealing site. Not only does it enhance the aesthetic user experience, it impacts upon the users' trust in the information on the site.

Palmer (2009) illustrates the impact of design on accessibility by noting that "content must be readable, an essential consideration of designers when selecting font size, color, page layout and structure (pg. 102)."

Accessibility

Web accessibility can be assured through careful consideration of back-end design. Use of easily readable background and text colours and the ability to increase text size ensures access to users with visual impairments and learning disorders. Text only options and the ability to view content without high level technology allows access to those with low broadband speeds and dated computer software. Accessibility is about considering the widest range of potential users and ensuring access to all.

According to the World Wide Web Consortium, "[i]t is essential that the Web be accessible in order to provide equal access and equal opportunity to people with diverse abilities. Indeed, the UN Convention on the Rights of Persons with Disabilities recognizes access to information and communications technologies, including the Web, as a basic human right. Accessibility supports social inclusion for people with disabilities as well as others, such as older people, people in rural areas, and people in developing countries."[11]

Williams et al. (2002) addresses the importance of accessibility in their evaluation of a health information website. They note the following criteria as important to the user experience; functionality of different platforms/formats; use of multimedia features; reliability of the host server; readability level and retrievability; background and text colours; page length, layout and typography, and text links for graphics.

2.2.4: The Web and Public Engagement

Early research into the ability of the Internet to form communities was divided between those who felt that 'cyberspace cannot be a source of real community and/or detracts from meaningful real-world communities' (Beniger, 1988; Gergen, 1991; Kiesler et al.., 1984; Stoll, 1995; Turkle, 1996) and those who thought that 'cyberspace can create alternative communities that are as valuable and useful as our familiar, physically located communities' (Pool, 1983; Rheingold, 1993). As the level of interactivity has grown considerably, aided by

11 http://www.w3.org/standards/webdesign/accessibility, last accessed January 6, 2010

user-driven applications, opportunities for online interaction and relationship building have increased dramatically.

Jankowski (2006) argues that "of all the promises and prognoses made about old and new media, perhaps the most compelling has been the possibility of regenerating community through mediated forms of communication (pg. 55)." He notes the development of this 'theme' through emergence of radio and television but stresses that it has reached "extraordinary proportions with the more recent emergence of 'virtual communities' online (pg. 55)." New media, he notes, "increase[s] the options available for audience members to become involved in the communication process, often entailing an interactive form of communication; and an increase in the degree of flexibility for determining the form and content through digitization of messages (pg. 56)."

2.2.5: Conclusion

Through careful consideration of the attributes listed in this chapter, public communication of science can be conducted via the Web that would yield a level of engagement previously restricted to face-to-face interchanges. One of the most important shifts to take place as the Web has developed, is that which Minol et al. (2007) describe as the 'read only' Web to the 'read-write' Web. This content shift has changed the way that people use the Web from an information source to a platform for interactive communication. It has altered the user role to one of co-creator, providing Einsiedel's 'active public' with a forum for participation.

With its inherent properties of accessibility and interactivity the Web represents one of the most comprehensive tools currently available to the field of biomedical science for the dissemination of information on research and findings. To realise its potential however, Web publishers must adhere to several principles of good Web practice. The following attributes have influenced the methodology implemented in this study, as outlined in the methodology chapter to follow.

Ensuring that users can identify credible sources online is a matter of significant importance. Transparent identification of author and publisher is essential to Web credibility. Factors such as design and choice of domain name have been shown to impact upon user's perception of a website's credibility, however Flanagin and Metzger's (2007) mention of depth of content and its link to credibility is worth noting.

Ease of navigation has also been shown to be of importance as it has a direct relationship to user satisfaction. The importance of a clear navigation system, which makes use of such features as consistent menus, drop down menus, homepage links on all pages and breadcrumbs to illustrate navigation paths, is as Krug (2000) notes, essential. Not only does clear navigation ensure that users access relevant information on the site, it increases the likelihood that they will return to the site.

Interactivity, when used effectively, gives the Web potential to, as Stout et al. (2001) state, become a "dynamic medium for influencing learning, attitude change and behaviour (pg. 721)." By placing control in the hands of the user, interactive features increase interaction giving users a more active role in their experience.

The most important element of any website is content. Effective use of all other attributes will not ensure a positive user experience if content falls short. Accuracy, currency and attribution of author and source are essential to the provision of valuable Web content.

Good Web design has a tendency to be relegated to the trivial. As Fogg et al. (2002) have shown however, 'design look' has an important impact upon user's perceived credibility of a website. Carefully considered design can also ensure accessibility for a range of users.

In making effective use of these attributes, biomedical science research institutes can develop websites that are seen by users as credible, are easy to use, provide relevant, timely and quality information and ensure a positive user experience. The next chapter will illustrate the extent to which this has been accomplished to date by examining science communication on the Web.

2.3: Science Communication on the Web

2.3.1: Introduction

Scientists played a critical role in two breakthroughs that led to the Web as we know it today. The first was in the late 1960s, when scientists at three universities connected their computers together as part of a project in computer science, creating the prototype Internet. The second took place two decades later when Tim Berners-Lee developed the origin of the World Wide Web as a means for teams of scientists spread around the world to communicate in an error-free, productive and inexpensive manner (Rzepa, 1999; Marlow, 1996; Trench, 2008). There can be no denying that conception of the Internet and the World Wide Web was deeply influenced by science, but has science made effective use of the communication medium it helped construct?

At a 2001 Internet Bounty Symposium held at the annual meeting of the American Association for the Advancement of Science, *Science News* editor Julie Ann Miller stated, "[i]n the past year, the number of websites presenting science and health news and background information has risen sharply. And the number of people who consult these sites has also climbed. A wide variety of observers predict that in the coming decades, the Web will replace newspapers, magazines, encyclopaedias and other traditional sources of information (pg. 244)." Miller notes the concerns this increase in scientific content on the Web raises and calls for more in-depth and considered research into use of the Web, learning through the Web, and applications of that learning. Since Miller's comments, the level of Internet use for communication between scientists and for the public communication of science has risen significantly.

Having already examined the field of Science Communication to determine appropriate methods for communicating science to public audiences and outlined key developments in Web technology that have led to the establishment of the Web as an ideal platform from which to reach vast audiences, this chapter examines science communication on the Web to date. Reviewing a number of studies which have been conducted in North America, Europe and Asia this chapter will; analyse use of the Web for intra-science communication; use of the Web for communication of science to various public audiences, taking a specific look at the issue of uncertainty; identify science Web users; and measure the impact of communication of science and technology via the Web in general and to specific audience groups. Finally, this chapter will summarise the findings of previous studies of science websites and the impact of those studies on my own.

2.3.2: Intra-science communication on the Web

Given the involvement of scientists in the development of the Intranet and the Web, use of the Web for scientist-to-scientist communication might be assumed to be significant. A few studies have explored the extent to which Web technology has impacted the way in which scientists work and communicate with one another.

Rzepa (1999) argues that while scientists have harnessed Web technology for communication via email "few use it as productively as they might for science communication (pg. 142)." Stating that the Web's "potential for changing some of the ways in which scientists can communicate with each other is substantial (pg. 149)", Rzepa outlines a number of uses of Web technology that would advance and further scientific communication. Reading his work today Rzepa's suggestions appear antiquated; however the principles behind them remain valid. He calls for harnessing 'the invention of the hyperlink' which allows communication between author and reader to take many forms and to be 'easily and transparently interlinked'; using the Web to 'gain wider feedback' for work prior to publication by means of online discussion with readers, a "new form of collaborative peer review mechanism (pg. 148)"; and online publication by reputable journals. Rzepa's arguments are validated by the fact that the concepts he puts forth have been widely adopted, to the point of being commonplace.

Writing at the same time, Wulf (1999) comments that "science is an immensely complex social structure, and the Internet has become an essential part of the fabric of it (pg. 133)." He outlines the many and complex ways in which the scientific community make use of computer technology and Internet communication. Like Rzepa, he forecasts the adoption of online technology by scientists as a means of enhancing communication between scientists. He proposes that "while Internet users are now acutely aware of the boundary between their own machines and the rest of the network, that boundary will blur and possibly disappear (pg. 138)", correctly suggesting that the power of the desktop computer will increase dramatically and that the ability to browse and access information remotely will increase.

Trench (2007) cites a number of examples to illustrate the impact of the Web on intra-science communication. The Human Genome project, made possible by Internet communication; the world of scientific publishing, transformed by developments in electronic publishing and open access; and a range of Internet-based media that have developed for the dissemination of scientific information to wider publics, are some of the most significant areas of science communication to have developed alongside the Web.

In *Internet: Turning science communication inside out?* Trench (2008b) continues his examination of the development of the Internet in professional scientific communication, noting two contradictions. First is the trend toward "easier collaboration across continents" facilitating collaboration, alongside the trend toward "greater fragmentation" leading to accelerated specialization or 'balkanisation'. The second contradiction he highlights is disturbances caused by electronic publishing, particularly an intensification of competition. He notes that the Internet facilitates many of the day-to-day routines of scientists, so much so that "the processes by which the Internet has come to fill this central place in internal science communication demonstrate well how technological innovations can be shaped socially to forms and functions not anticipated by the originators and first adopters."

Of greater significance to this study than intra-science communication on the Web are ways in which the Web has come to be used as a means of communicating science and technology to various public audiences.

2.3.3: The Web and public communication of science

In its earliest incarnation, the Web was a tool accessible only to an elite group of scientists and researchers. As it has developed over time, the Web has become a powerful tool for mass communication, connecting users previously divided by geographical, social and economical boundaries.

In *Touring the Scientific Web*, Peterson (2001) seeks to measure the breadth of scientific information available to Web users, while addressing the positive and negative attributes of that information. Highlighting the abundance of websites dedicated to sharing information on science topics ranging from astronomy to physics, medicine to geometry, he emphasises the breadth of high quality, informative scientific information available to anyone with access to the Web. He notes however that there are gaps in the Web's coverage of science, citing the lack of "timely reports devoted to conveying and explaining scientific research or medical advances to the general public (pg. 250)." An important fact highlighted by Peterson is that despite the abundance of science news made available through a myriad of science news websites, the vast majority of news items stem from a short list of primary sources, namely Science, Nature, the New England Journal of Medicine and the Lancet. "The World Wide Web," he notes, "has provided the general public with access to massive amounts of information that was previously difficult to find and sometimes generally inaccessible. It is one of the ironies of how this vast data repository operates that, when it comes to news, a handful of sources can set the agenda for the dissemination of scientific, technical, and medical information (pg. 253)."

Commenting on the role of the Web in the public communication of science and technology, Trench (2008b) notes “the development of Internet-based media on the dissemination of scientific information beyond the research communities” which he sees as accelerating the “erosion of boundaries between previously distinct spheres of communication.” He notes that “institutions have adopted a public communication model, that of journalism, in the distribution of information…. these institutions’ practice on the Web expresses further how the boundaries between professional communication and public communication are eroded… [illustrating the way in which] scientific communities use general news media to communicate with each other.”

Credibility & Science on the Web

The issue of credibility is of particular relevance when examining the publication of scientific content on the Web. Peterson (2001) discusses the source of scientific information stating that reports from reputable research institutes can be seen posted alongside reports written by journalists for media organisations and items posted on individuals’ websites with no differentiation. This can make it difficult for a user “to assess how seriously one can take a given report (pg. 251).” In other cases, he notes, sites fail to identify the source of their information at all.

Triese et al. (2003) also examine the issue of credibility by investigating factors that influence the perceived credibility of a science website. They note that the “explosion of information about science on the Web may pose a challenge for sites… it may be difficult for quality sites to distinguish themselves from competitors offering information of lower quality or veracity (pg. 310).” Commenting that the user is faced with a challenge in surfing the Web for science information, they state that “knowing which of the many sites available contains information high in quality, currency and accuracy (pg. 310)” is difficult. In their study, Triese et al. recruited 497 male and female undergraduate students to examine domain credibility and the impact of science involvement on credibility. They found that those factors that attract people to a website are credibility, ease of use, attractiveness, organisation and writing quality. Indicators of credibility include sites that clearly display the credentials of authors who have written the sites’ content; the date the pages were last updated; the Web site’s policy on confidentiality of data provided by its users’; references for the sources of data used in the information; the site’s sources of funding and advertising policies. They note that audiences with greater understanding of science will “evaluate the quality of arguments contained in the message itself” while a less involved audience member will “lack the ability to process a message [and will therefore] form opinions about the message based on factors other than the arguments contained therein (pg. 316)."

Along with Peterson and Triese et al., Trench (2008a) examines the credibility of information published via the Web commenting that; "[t]he Web's characteristics as a publishing medium, most obviously its juxtaposition of information and perspectives through search results and hyperlinking, may contribute to heightening the sense of uncertainty." He does however note a paradox, that

> "using the Web's hyperlinking capacities, and conscientiously connecting and comparing a range of perspectives and course-types, creative Web publishers can offer users a fuller picture and an understanding of the bases of uncertainty. They can do so, for example, by providing pointers to sources other than their own that may confirm or qualify the information for which they are directly responsible. They can assist the user further by adding information about information, indicating how their own information has been compiled, and offering responsible and critical assessment of competing claims and diverse contributions."

In doing so, Web publishers can mitigate the risk of having Web users dismiss their content on the basis of lack of credibility. But as Trench argues, opening scientific publication to the public raises challenges for both parties concerned. For scientists, he notes, a key question "is how and whether the traditional standard of peer review should be applied in this changed environment". For Web users, on the other hand "a closely related question is that of the validation and interpretation of information found by hazard or purposeful searching."

2.3.4: Identifying science Web users

With the increasingly vast amount of science information available on the Web, the need arises to examine the various public audiences accessing the content. Who are science Web users?

J. D. Miller (2001) examines the audiences of science information on the Web reporting on a 1999 study which maps the rise of Web use over an extended period. He notes that "as with virtually all new technologies, including the automobile and television, better educated and more affluent citizens have acquired and utilized computer technology first (pg. 257)" acknowledging a 'digital divide' between those with access and those without. Taking a deeper look at science Web users, Miller examines reasons why the Web is used to acquire scientific information. The potential motivations he considers include; education; having children at home; civic scientific literacy; biomedical literacy; attentiveness to science and technology policy; attentiveness to biomedical research; news reading; science television viewing; and public library use. The results show that in identifying those who seek science information on the Web, the strongest predictors were scientific literacy, education, gender and age. While the strongest predictor for looking for health information on the Web were biomedical literacy and education. This, he states, "indicates that individuals who seek scientific or health information on the Web already have a better than average level of knowledge and appear to be seeking either more recent information or more advanced information about some subject (pg. 269)." He comments that these results should not be surprising, as "they emphasise the historic and continuing role of education in creating and using new technologies" and notes that "it is likely that the absence of education is the primary barrier to meaningful access to the Web and related technologies (pg. 270)."

Horrigan (2006) wrote the PEW Internet and American Life Project[12] which updates Miller's findings on use of the Web to find scientific information. His statistics show that as of 2006 "40 million Americans rely on the Internet as their primary source for news and information about science (pg. i)" and that "the Internet is the source to which people would turn first if they need information on a specific scientific topic (pg. i)". Beyond using the Web as a resource for attaining information however, user experience has the ability to influence attitudes toward science. The study showed that "those who seek out science news or information on the Internet are more likely than others to believe that scientific pursuits have a positive impact on society (pg. iii)" and that "those who go online for science news and information are more likely to strongly agree with propositions about science's positive role in improving society, the quality of human lives, and the nation's well-being (pg. 15)." Reaching audiences however requires forethought as the study shows that "search engines are far and away the most popular source for beginning science research among users who say they would turn to the Internet to get more information about a specific topic (pg. v)." A site that makes use of search engine optimisation would enhance the potential that interested users would reach the website.

2.3.5: Measuring the impact of science websites

Having examined use of the Web as a means of communicating science to public audiences and identified the extent, and particular characteristics, of that audience, efforts to measure the impact that science content has on users must be examined.

[12] The PEW Internet Project is a non-profit, non-partisan think tank that explores the impact of the Internet on children, families, communities, the work place, schools, health care, and civic/political life. The Project aims to be an authoritative source for timely information on the Internet's growth and societal impact. www.pewInternet.org, last accessed January 7, 2010

In an effort to measure the impact on users of science content on the Web Mitsuishi et al. (2001) established the Scientist Library, a website featuring biographical and research-oriented information on 88 biologists. Having created the site, the team then evaluated its content to determine the effectiveness of their concept of 'showing the scientist as a person' as a tool for science communication. They state that "the Scientists Library was constructed with the goal of transmitting each scientist's personality and research to give a global view of the present state of science (pg. 233)." The site contained a short biography, photograph, brief explanation of the research and research image for each of the 88 featured scientists. Interviews were conducted to survey user experience to determine if scientist biographies were an effective tool for science communication (78 percent felt the content was effective), the uniqueness of the project (77 percent had never seen a site like it before) and the degree of difficulty of the content perceived by users (45 percent of those who felt the content was 'difficult' or 'somewhat difficult' had studied biology at the university level). This showed that prior level of knowledge had no impact on the perceived difficulty of the content. Mitsuishi et al. argue that "current progress of science is often not transmitted accurately or the attempt to communicate science is not even made because of the specialization inherent in science interferes. In our project however, we found that people wished to have information about contemporary science" and that the Web provided the best medium with which to do so (pg. 239).

Koolstra et al. (2006) while not contradicting the aforementioned PEW report, provide perspective with which to consider statistics that show the Web as the dominant form of media for scientific enquiry. Their work compares the mediums of television and the Web to determine the best means for science professionals to communicate with the public. To do so, they look at how the public uses both mediums, how effective the mediums are for transferring information and how reliable the mediums are considered to be as sources of information. They argue that "the old mass medium television should still be regarded as the most important medium for science communication (pg. 1)". To reach this conclusion, Koolstra et al. examine statistics from a range of existing studies conducted mainly in Europe (particularly the Netherlands) which showed that access to television is significantly higher than to the Web; information received from television is more easily recalled because "audiovisual information is stored in memory with two separate but associated codes (visual and verbal) (pg. 4)[13]"; and that 84.2 percent of respondents trusted television as an information source.[14] They note that 61 percent of respondents to an American study carried out by Princeton Survey Research Associates in 2005 chose the television as their main source of information while 11 percent chose the Web. In conclusion, Koolstra et al. state that "television should be included [over the Web] in the choice of science communication professionals when they aim to promote public

[13] Koolstra et al.. concede that recall of some content on the Internet, such a videostreaming, is highly comparable to television.
[14] This statistic is derived from a 2005 survey conducted by Trouw, the Dutch newspaper, in 2005.

awareness, interest, and understanding in science and technology (pg. 5)" but address the issue that "the strong lead of television may disappear in future because there is evidence that the younger generations use and value the Web more than older generations (pg. 5)." They predict that a shift from the old medium of television to the new medium of the Web will have occurred in under a decade.

Addressing particular audiences

Looking to one particular segment of Web audiences by addressing the relationship between science communication on the Web and the media, Duke (2002) writes about the Web as a powerful medium for science public relations. She notes that while scientists are becoming "increasingly convinced that it is important to explain their work to a wider audience (pg. 312)" few studies have focused on use of the Web for communication with the media despite the fact that "many public relations practitioners who specialise in science topics were among the first to use the Web (pg. 313)." Duke's study of science public relations practitioners found that they have "embraced both the Web and e-mail and view these tools as essential in their media relations work" and that it is the practitioners' perceptions that "e-mail and the Web will help increase media coverage (pg. 321)." While this study is dated, it is nonetheless interesting to note the early adoption of the Web by those working in the field of science communication.

Dumlao and Duke (2003) look to yet another specialist audience in their examination of how the Web and e-mail are used by science writers. This study builds on the research of Trumbo et al. (2001) which showed that members of the National Association of Science Writers made considerable use of the Web and e-mail in their work, which was determined to be the case because of the inherent technological advancement of science writers over other journalists. Dumlao and Duke conducted interviews with a subset of NASW members to determine ways in which the Web had changed the way they worked, how they use the Web for work, how they feel about the Web's influence on their work and whether or not they have concerns about the quality of Web -based information. What they found was that "e-mail and the Web are having a tremendous impact on the practices of science journalism and on the lives of science writers" but that "although these new technologies speed information in ways that benefit their work and the dissemination of information, not all effects are positive (pg. 302)." While interviewees were enthused by the ease of access to science information online, they urged Web users to practice good judgment when reading scientific information on the Web, noting scepticism about information quality.

Yet another target audience is considered by Steinke (2004) who argues that the Web has the ability to influence girls' and young women's perceptions of [science] professions and potentially their occupational choices. She argues that websites "provide an opportunity for 'vicarious contact' with women scientists and engineers when girls are unable to interact directly with real-life models (pg. 10)." Surveying the content of 27 websites according to three criteria; increasing girls' knowledge of science, mathematics, engineering and technology; providing information about careers in these fields; and setting up opportunities to interact with professionals in these fields to act as role models and mentors, she found that "many of the sites meet the first two… [criteria]… and a few are even using the interactive features of the Web related to the third (pg. 20)." Steinke notes that because of unique qualities of the Web, "these websites may help counter existing cultural stereotypes of women scientists and engineers, leading to changes in public perceptions needed to narrow the gender gap in science, engineering and technology (pg. 20-21)."

Case Study: The Why Files

Eveland and Dunwoody (1998) and Dunwoody (2001) report on a nine-year study of a Web site for science information called 'The Why Files', still being published at http://whyfiles.org/. The study sought to understand how "diverse members of the public may make use of such a website to learn about science (pg. 285)" by looking at the site's audience, number of visitors, and visitors navigation patterns. They found that the typical user was male and well-educated, a "pattern that reflects both Web users generally and the science-attentive segment of the public particularly (pg. 285)" and is in line with both J.D. Miller (2001) and Horrigan's (2006) findings; that up to 25,000 people visited the site during a two-week cycle and that most visitors followed a linear pattern through the site. Beyond these results it is interesting to note that users of The Why Files spent a great deal of time trying to figure out where they were at the site. It emerged in the 2001 revisit of the study that the typical linear pattern was a result not of users reading their way through the site content page by page but of a panicked clicking on the Next button to get through the site. This supports the previous chapter's emphasis on clear navigation, an issue of critical importance when it comes to site design as it can prevent users spending the bulk of their time orienting and not learning.

2.3.6: Previous studies of science websites

Inherent to this study is an assessment of ways in which the Web is being used as a tool to communicate science to public audiences. Four similar studies have previously been conducted which greatly impacted upon my own. The methodologies and findings of these studies are outlined here.

Lederbogen and Trebbe (2003) articulate the need for the Web as a science communication tool. They state that "[i]nsufficient understanding of science leads to problems of acceptance or to a blind belief in the magic abilities of scientists (pg. 350)." Either reaction, they argue can be problematic, at worst potentially leading to a lack of public support for research. They note the tradition amongst scientists of having difficulty communicating with the public but state that past initiatives aimed at increasing the public understanding of science in Great Britain and the United States have demonstrated the importance of the involvement of scientists in establishing a permanent dialogue between science and society. The Internet, they argue can provide a much needed tool to facilitate this dialogue.

Their 2003 study was a content analysis of the Web pages of German universities and non-university-based research institutions which asks "has the Internet provided new possibilities for global science communication (pg. 333)?" Stating that German universities are aimed at initiating dialogue with society, they comment that "the Internet is likely to become one of the most important means of communication (pg. 333-334)." Their study aims to determine the quantity and quality of science and research information presented on the selected websites. Also of interest to Lederbogen and Trebbe was whether or not the sites addressed specific audiences.

On a whole, 22 sites were examined as to their appearance and their appeal to target audiences. Specific criteria included the analysis of text content, style, design, multilingual presentation, use of technical terms, use of specific Internet usability tools (such as hyperlinking) and academic presentation (such as referencing).

Lederbogen and Trebbe find that the majority of the sample addresses target specific audiences and that depending on the group being addressed, special patterns of navigation and interaction are offered. "Students, scientists, and alumni seem to be the main targets of communication by universities. The scientific institutions not involved in teaching try to appeal to scientists, although they try hard to attract other members of society as well (pg. 343)." They find that the principal content on the sites is an overview of the nature and context of research projects, and qualifications of the staff, while only a few universities (23 percent) "provide the user with detailed reports or results of their research (pg. 344-345)."

Unique Web properties are not widely used, as 77 percent of research institution and 70 percent of university sites consist of plain written text. "Among these texts, very few were obviously exclusively designed for publication on the Internet (pg. 345)." Fewer than half of the documents examined in their study were dated. Of those that were dated, the majority were older than six months. Ledgerbogen and Trebbe conclude that,

> "Scientific websites still do not seem to appeal to a clearly defined target group... The majority of websites still cater to the interest of their own scientific community... We find many research projects and very few specific results are described on websites.... Most websites do not fulfil the user's demand for up-to-date and easy-to-understand contents.... Many texts are difficult to understand due to the frequent use of technical terms that are not explained further.... Altogether, public relations undertaken for top German research still exhibits some major flaws (pg. 350)."

These findings are repeated in other similar studies to follow.

In a study of 115 Irish-produced websites that present scientific information including those of scientific research and education institutions, national scientific bodies and government agencies, Trench and Delaney (2004) find that they used "almost exclusively a one-way model of communication, rarely offering Internet users the means to contribute to information and argument." To conduct the study, a coding framework was developed that examined widely recognised Web content and site design guidelines. This framework assumed that information that was tailored for specific audiences was more likely to be 'actively received' than information that was more generic in character.

Trench and Delaney's findings show that "[g]iven the importance attached in research communities to Web presence it is fair to take the websites of research organisations as reflecting their public communication/ public relations strategy… we can say that the PR strategies of Irish research organisations are focused on narrow sectors." These findings are in line with Ledgerbogen and Trebbe and confirmed that Irish scientific institutions use the Web more to promote themselves to professional and business audiences than to share information about their activities with diverse social groups. Trench and Delaney comment that "our assessment was that the publishers of these sites were using the Web mainly to promote themselves to peers, partners and clients and, very much less, to communicate with diverse publics."

Just as Lederbogen and Trebbe's results illustrate trends in Germany, Trench and Delaney's study shows that Irish research organisations use the Web principally for self promotion, only make use of Web facilities that enable dialogue in limited amounts and gather very little feedback from users. They conclude by stating that "for the general Web user looking for information on current scientific developments, international sites will remain the most-used resources" a fact further supported by the Massoli study.

In 2007, Laura Massoli of the Italian Communications Regulatory Authority conducted a study on the websites of several European public research institutions[15] aimed at analysing the science communication model chosen and implemented on institutions' websites. She further sought to define whether use of the Web as a communication tool 'added value' or simply presented information that could have been presented through another choice of media. Massoli's aim is to understand whether the "chosen model is simply a transmissive and informational one or one based on relation-building (pg. 1)." Selected websites were analysed according to the following criteria; presentation of the institutional identity; engaging the public; the scientific dimension, taking into account authoritativeness, transparency and credibility; services to the users; the research network; and usability and accessibility.

Her findings showed both positive and negative examples of use of the Web for science communication. With regard to her search for 'added value' she noted, like the previous two studies, that European research institutions tended to use the Internet mainly as a tool to convey scientific-institutional information. "The user is easily able to reach content and news about a scientific institution, its projects and research activities, and may contact its advisors or read and download brochures and various documents. Thus the website provides the minimum required information, yet it appears as a half-filled container (pg. 14)." With regard to use of the Web to promote scientific culture and engage the public, she commented that the "services and possibilities provided by the websites have all been found lacking. The interaction and participation opportunities are quite rare and the ones that have been detected are more devoted to specialists rather than aimed at involving the general public. A similar framework applies to the online implementation of services for different user groups. (pg. 14)"

As a result, Massoli showed that engagement and the use of interactive features were rarely put into use in her sample. The best examples for best practice in this regard, she feels, can be seen in the US and the UK, where "investment and experimentation in these fields (pg. 14)" has been longstanding.

Most recently, a 2008 content analysis of the websites of Polish science institutions was carried out by Jaskowska which considered a group of audiences; scientists; students; science journalists; government; industry; teachers and the wide public. It asked what efforts were

[15] The countries involved in the study were the 27 EU member countries, the EU candidate countries (Croatia and Turkey) and the three EFTA countries (Iceland, Norway and Switzerland). The US was added for a total of 33 countries.

being made to provide these audiences with targeted information and dialogue. Her study, which evaluated the Web pages of over 200 institutions, found that "there is little information addressed to the wide public, no information for teachers, science journalists. The results also show… there are too little activities for *public understanding of science and technology*."

In analysing the websites of higher educational institutions, Polish Academy of Science institutions and Research and Development institutions, Jaskowska asked three key questions; what audiences are targeted; what type of information is directed at each targeted audience; and is the communication bilateral or unilateral? Her results showed that a high majority of the sites concentrated their attention on just one audience—scientists. 92 percent in the case of higher educational institutions, 93 percent of Polish Academy of Science Institutions and 74 percent of Research and Development institutions. Jaskowska's findings equate with those of Massoli, Trench, and Lederbogen and Trebbe.

2.3.7: Conclusion

While use of the Web as a means of communication between scientists has impacted the way scientists work in significant ways, this study is more concerned with use of the Web for communicating science to various public audiences. A number of methodologies and practices emerge in the literature which if adopted would enhance user experience and result in effective use of the Web for science communication.

As levels of access continue to rise, the Web represents an opportunity for the scientific community to openly share information with vast numbers of users. Peterson (2001) shows the breadth of science information available on the Web but questions the quality of the information. Trench (2007) notes the development of Internet-based media used by research communities to disseminate information to the public, leading to an 'erosion of boundaries' between previously distinct groups. Credibility is essentially at the centre of successfully providing information to online audiences. Triese et al. (2003) identify the following factors as having an important impact on website credibility: clearly displaying the credentials of authors who have written the sites' content; the date the pages were last updates; the website's policy on confidentiality of data provided by its users'; references for the sources of data used in the information; the site's sources for funding, and advertising policies. By considering these factors, as Trench (2007) states, "creative Web publishers can offer users a fuller picture" and mitigate a negative reaction to uncertainty in the science.

Both J.D. Miller (2001) and Horrigan (2006) identify science Web users as predominantly well-educated males, a small fraction of potential online audiences. Efforts must be made if a wider segment of the population is going to begin accessing science information online. One potential means of drawing larger audiences is the use of innovative combinations of text, audio and video files using new media technology. Koolstra et al.'s (2006) comparison of the impact of television and the Web as communication mediums illustrates just how powerful a resource can be created by bridging the two media. Mitsuishi et al.'s work suggests another potential means of attracting new audiences to online science content. Public audiences respond well to science information that is presented in way that can be grasped on a human-to-human level. The provision of researcher biographies and other forms of contemporary science on institute websites can have a positive impact upon user experience.

The above mentioned studies, and in particular the findings of previous studies of science websites, have had a strong influence over the methodology I have implemented in my own study as discussed in detail in the next chapter.

2.4: Literature Review Discussion

2.4.1: Introduction

Effectively communicating science to the public is a complicated task to which a set of standards is difficult to apply. The task becomes even more complex when matters of uncertainty arise. Examples such as the BSE crisis, the GM food debate and more recently the emerging field of nanotechnology illustrate this quite clearly.

From this review of the literature however, a number of points are drawn which guide science communication efforts on the Web if considered fully by practitioners. Biomedical research institutes can 1. communicate information effectively by forming a more complex understanding of 'the public', and targeting content at particular segments of their audience; 2. accepting that the public has a low level of scientific literacy but are quite capable of understanding complex ideas and therefore providing in-depth yet accessible information; 3. endeavouring to take an open approach to communication, in order to build trust, which does not attempt to shield the public from uncertainty; 4. blending different approaches to, or models of, communication according to the particular audience, issues or context through a range of Web technologies that allow for interactivity and the creation of user driven content.

2.4.2: Science Communication

The literature has given us a more complex understanding of the public. No two 'publics' are alike; rather audiences are shaped by the science issue at hand, the time and place. Context is of the utmost importance when considering public experience (Einseidel, 2008).

Burns et al. (2003) provide us with a simplistic definition of the public that fails to acknowledge the heterogeneity of each of their four defined groups. Their categorization and definition of groups needs to be taken further. Durodié's (2004, pg. 86) observation that "the public display an understandable proclivity to prioritise emotion over reason" as one of a series of arguments against the power of dialogue as a effective tool has been negated by the arguments of Jackson et al. (2005).

Einsiedel (2008) presents a strong definition of the public as 'active'. While recognition of individual knowledge is important, acknowledgement that the public have a role to play is central to effective communication. The Web then provides an appropriate platform; online communication of science facilitates an active public role via its attribute of interactivity.

Decades of measurements have shown that the public in general does not have a high level of understanding of science. J.D. Miller's (1992; 1998; 2000) work has taught us much about the way adults acquire scientific knowledge thus enabling the development of more informed methods of science communication. The questioning of 'how much understanding of science is enough' is the basis of Shamos' (1995) work. His assertion that true scientific literacy will not be attained by most adults is fair. This should not however be taken to mean that providing the public with access to information to help them become more expert is unnecessary. Provision of information that caters to a range of publics, rather, should be part of the policy of any scientific institution. As Doble (1995, pg. 99) states, "the general public has the ability and willingness to assess thoroughly, even very scientifically, complex issues" and should therefore be given the opportunity to do so.

S. Miller (2001) states that the knowledge gap between scientists and non-scientists is never going to be filled. Nor does it need to be. It is essential that the formal education system provide young people with a strong grasp of STEM subjects, however learning need not end when formal schooling ends. The scientific community, by providing an opportunity for the public to educate themselves about particular science issues through access to in-depth information about research, can enable further education and heighten awareness of science and its role in society. Thomas and Durant (1987) believe that to be scientifically literate is not to be expert in any one thing but to be able to effectively deal with scientific matters shows that in-depth knowledge is less important than an ability to recognize the impacts, both negative and positive, of science. With that in mind, Scheufele's (2007) concept of the 'cognitive miser' should influence the provision of information by science communication practitioners, as it highlights the critical importance of information quality not quantity, illustrating that attitudes may be formed on the basis of a small amount of knowledge.

A number of perspectives on the influence of knowledge on attitude formation have been presented, each with a slightly different conclusion drawn. Evans and Durant (1995) show that the more the public knows about *contentious* research the more sceptical it becomes, though this is not necessarily a negative outcome as Bauer (2008) shows that the public can be sceptical while still being supportive and that scepticism can in fact be empowering for the public, heightening its ability to recognise quality science over exaggerated claims. Evans and Durant also note however, that *interest* may well be more important to attitude formation than knowledge while Peters (2000) shows that attitude is more strongly influenced by context than knowledge. Considering these varying points of view, research institutes would do best to openly share research information in order to increase understanding and appreciation of science. In doing so however, a relationship of trust must be established.

Open communication of scientific research, its aims, methods, findings and implications, is imperative to building and maintaining public trust. The websites of scientific research institutes should as Shapin (1992) states share knowledge openly. This becomes even more important in the case of areas of science characterised by uncertainty as argued by Doble (1995). In sharing knowledge openly, an absence of bias is critical. A balanced delivery of fact and finding would, as Valenti and Wilkins (1995) state, allow the public to consider information, not push them to accept one view over another. While opinions should be debated along with facts, Durodié's argument that local knowledge is *mere* opinion is too dismissive of the role the public plays in science and the influence of public opinion of policy making. Rather than harm public support, openly communicating uncertainty and the steps taken to address potential negative outcomes serve to enhance the public's trust in the scientific community.

Engaging in public communication efforts in the early stages of research can further help maintain support. Upstream engagement efforts may prove an effective means of including publics in the scientific process, as Wynne (2006) suggests. Jackson et al. (2005, pg. 352) identify the need for upstream engagement with clarity in listing its three purposes;

1. increased democracy by promoting open and transparent decision making
2. greater trust and confidence in the regulation of science and decisions taken
3. better decision making

Successful attainment of these three outcomes should be the goal of public engagement efforts.

Early approaches to science communication have been criticised for their failure to affect public understanding of science. This in turn led some practitioners to adopt new methods of engaging the public. One-way, top-down models were in many cases replaced with two-way, participatory models of communication. But Wynne (2006) has shown that the presumed failure of the deficit model was based on incorrect assumptions undermining justification for its replacement and Trench (2008b) shows that all three models, deficit, dialogue and participation are valid and have their place. A richer understanding of the complexities of the public brings with it acknowledgement of the fact that there is no right or wrong model. Just as public attitudes are shaped by the context surrounding a given science issue, science communication models are complex methodologies that cannot be pegged as effective or ineffective in all instances. The communication of science to the public must be dealt with on a case by case basis. Consideration of context is critical to communication model selection for as Irwin (2006) states, "there are substantial limitations to the 'toolkit' approach (pg. 51)." Well considered science communication efforts should, as S. Miller (2001, pg. 118) states, "be much more aware of the nature and existing knowledge of the intended audience."

Some of Durodié's (2004) points against the fashion for dialogue are valid; science communication can at times 'dilute the detail' in an attempt to popularize science, public engagement activities can 'politicise the decision-making process' and unsuccessful public engagement efforts can dissuade scientists from future participation. But Durodié takes his argument too far in using these points to argue against any form of dialogue. Given the many strong arguments in favour of open communication of scientific research (Wynne, Irwin, Shapin, Doble) upstream engagement seems like a logical development. If the public are to feel that their opinions and ideas are valued by the scientific community, they must be attained and considered from the start, incorporated into action as research progresses. To inform the public of issues of risk, uncertainty, or ethical quandaries only after they have emerged seems counterintuitive to true engagement.

2.4.3: Web Communication

The World Wide Web provides an appropriate platform from which the scientific community can communicate with public audiences. Over the last decade, access to the Web has increased dramatically. What was once a medium restricted to a small portion of the global population has exploded into a mass-medium like no other. Not only are more individuals accessing the Web, they do so more frequently through mobile devices. It is now possible to be 'connected' from just about anywhere. While the Web presents a powerful means of communicating with a variety of audiences, mere presence online is not enough to ensure that audiences are connected with or satisfied. A number of key points must be addressed in order for online presence to deliver effective communication for practitioners.

Alongside increase in access, a rapid increase in Web content has occurred. This however has highlighted the importance of posting high quality science information online, and of ensuring credibility of a research institute's website. Transparent identification of author and publisher is essential as are factors such as design (Fogg, 2002), choice of domain name (Triese et al., 2003) and depth of content (Flanagin and Metzger, 2007).

Effective navigation has a direct relationship to user satisfaction. A clear navigation system not only ensures that users access relevant information, it increases the likelihood that they will return to the site, as Krug (2000) notes.

Interactivity as a concept was central to the earliest development of the Web but the means of interactivity have increased greatly in recent years. Ongoing development of Web technologies is enhancing opportunities for interactivity between users. Minol et al.'s (2007) description of the shift from the 'read only' Web to the 'read-write' Web illustrates the changing way that people use the Web. While the earlier phase enabled the dissemination of information in keeping with the deficit model of science communication, development of the Web alongside the field of science communication has seen the role of user shift to one of co-creator. This has in turn provided research institutes with a forum for dialogue with and participation by Einsiedel's 'active public'.

The most critical element to any website however is content. A website that delivers on all other attributes will still fail if the content is inadequate. A number of scientific research institutes provide users with information about the institute, its founding, history, board of directors and list of staff. While this information can be helpful to some users and should be present, a strong website will view institutional information as secondary content. The science research being conducted by the institute, its aims, goals and potential outcomes is of greater interest to users and has the potential to enhance user knowledge. By providing in-depth content pertaining to research, and doing so in an accessible, accurate and timely manner, and making use of interactivity features that enable users to communicate with the scientists and one another, will ensure that the communication platform is well utilised.

2.4.4: Science Communication on the Web

The question remains 'has science made effective use of the communication medium it helped construct?' The answer is that it is just beginning to. While some scientific research institutes make creative and innovative use of the Web's capacity for information sharing and interactivity, many use it only for posting basic content. A number of studies have been conducted to examine use of the Web by the scientific research community. These studies have significantly influenced the development of my own, which aims to assess current use of the Web by biomedical science research institutes in the UK, Ireland, Canada, the US and Continental Europe to determine the extent to which this powerful communication tool is being used to or near its potential.

Trench (2007a) notes one of the most significant impacts of the Web for the communication of science to the public is the accelerating "erosion of boundaries between previously distinct spheres of communication." through "the development of Internet-based media on the dissemination of scientific information beyond the research communities." Those research institutes which openly publish reports on their research projects are effectively allowing the public into the lab, providing access to knowledge previously restricted to the scientific community.

The power of the Web is not without its limitations or risks however. Credibility is a significant concern. Triese et al. (2003) found that those factors that attract users to a website are credibility, ease of use, attractiveness, organisation and writing quality. Trench (2007a) notes a paradox in that certain Web characteristics such as hyperlinking, may contribute to heightening the sense of uncertainty when it comes to source credibility, but also enables 'creative Web publishers' the opportunity to "conscientiously connect and compare a range of perspectives and course-types, offer[ing] users a fuller picture and an understanding of the bases of uncertainty."

J.D. Miller's (2001) identification of science Web users links to his (1997) categorisation of the public. The science Web user is part of the *attentive* public, with an above-average level of interest in and existing knowledge of particular science issues. In his work on identification of science Web users, Horrigan (2006) illustrates just how powerful a communication tool the Web is in showing that user experience has the ability to influence attitudes toward science.

A number of studies illustrate the potential impacts of communicating science online. Koolstra's (2006) study illustrates the growing impact of the Web as a communication medium as it continues to merge the visual and verbal through various online technologies. The Web today, a blend of text, audio and video has the potential to be the most powerful medium in history for the communication of science to the public. Stienke's (2004) work, which introduces the concept of 'vicarious contact', illustrates how interactive features can be successfully applied to enable relationship building between users and further supports Horrigan's findings on the influence of the Web on attitudes toward science.

Lederbogen and Trebbe's (2004) examination of the websites of German university and non-university research institutes found that "public relations undertaken for top German research still exhibits some major flaws (pg.350)." Their examination of websites showed that unique Web properties were not widely used; very few texts were obviously exclusively designed for publication on the Internet; fewer than half of the documents are dated and of those that are dated, the majority are older than six months; very few specific results are described; most websites do not fulfil the user's demand for up-to-date and easy-to-understand contents; and many texts are difficult to understand due to the frequent use of technical terms that were not explained further. Lederbogen and Trebbe concluded that, "the majority of websites still cater to the interest of their own scientific community (pg. 350)."

Similarly, Trench and Delaney (2004) found that Irish science websites used "almost exclusively a one-way model of communication, rarely offering Internet users the means to contribute to information and argument." Their examination of more than 100 Irish science websites showed that Irish research organisations used the Web as a means of promoting themselves and "[made] little use of Web facilities for facilitating dialogic or trust-building communication with wider sectors, and are in general little interested in feedback."

Massoli's (2007) findings showed that European research institutions tended to use the Internet mainly as a tool to convey scientific-institutional information. With regard to use of the Web to promote scientific culture and engage the public, she commented that the "services and possibilities provided by the websites have all been found lacking. The interaction and participation opportunities are quite rare and the ones that have been detected are more devoted to specialists rather than aimed at involving the general public (pg. 14)." As a result, Massoli states, "engagement and the offer of interactive services emerge as the weakest points and only some prominent scientific institutions, from advanced countries deeply involved in research and scientific communication (notably the US and the UK), have been promoting an initial investment and experimentation in these fields (pg. 14)."

Finally, Jaskowska (2008) shows that the majority of Polish science research websites concentrate on just one audience—scientists. 92 percent in the case of higher educational institutions, 93 percent of Polish Academy of Science Institutions and 74 percent of Research and Development institutions. Like Lederbogen and Trebbe, Trench and Delaney, and Massoli before her, Jaskowska's study shows that the research institutes' websites which she examined catered to their own community and made very little effort to communicate science to public audiences by means of the unique properties available to them on the Web.

2.4.5: Conclusion

While the Web is a particularly well suited platform from which biomedical research institutes can communicate their research to public audiences, studies have shown that an opportunity is, by and large, being missed. Research in the fields of science communication and web communication has produced a body of knowledge on the topic that could be interpreted as guidelines for best practice. As identified in studies mentioned above, the Web continues to be used by research institutes as a means of promoting themselves among their peers rather than using the medium's inherent properties of transparency and interactivity to facilitate dialogic communication with public audiences. Yet there can be little doubt as to the power of the Web as a tool for knowledge sharing, community building and even influencing attitudes toward science.

3: Methodology

This study examined the websites of biomedical research institutes in the UK, Ireland, the US and Canada to determine whether or not the trend of merely using the Web for promotion to the scientific community is changing. It analysed the content of websites according to attribution and transparency; range and quality of content along with content currency; use of interactivity features; consideration of navigation; effective design; and provision of features that ensured accessibility. Website quality was determined by the detection of content that provided timely insight into current scientific findings; created opportunities for user interaction; made use of multimedia technologies to further understanding of scientific content; and used well-organised navigation and effective design to enhance user experience. Details of the criteria used in this study are outlined below.

The principal question of this research was 'to what extent do biomedical research institutes use the Web as a means of communicating science to public audiences?' Methodological triangulation was used; an extensive literature review was conducted to identify existing trends, methods of Web communication and to analyse the results of similar studies conducted previously. The findings of the literature review, as outlined in the Literature Review Discussion chapter, directly influenced the coding framework established to carry out content analysis of the websites of 68 biomedical research centres in the United Kingdom, Ireland, United States, Canada and Continental Europe. The content analysis, in measuring the presence of a range of criteria on each of the websites provided extensive quantitative data. In analysing the data, overall trends emerged which allowed for qualitative analysis. Following preliminary analysis of this data, a questionnaire to survey communication practitioners in the same institutes was developed to validate the findings of the content analysis. Questions included sought to further inform the motivations behind those trends emerging from the data and to confirm assumptions that trends were the result of practitioner's intentions.

Country Selection

The websites selected for this study were located in the United Kingdom, Ireland, the United States, Canada and Continental Europe. As my place of work was a biomedical research institute in Ireland, I was keen to examine use of the Web in other institutes similar to my own. Ireland was an obvious starting point. A native of Canada, I was keen to examine the websites of institutes in that country. As both countries are neighboured by and heavily influenced by nations larger in land mass, population, number of research institutes and funding for science, inclusion of the UK and the US heightened the indications of the data. A small sample of websites from Continental Europe was included to determine whether or not cultural differences represent themselves on the Web. I was interested to note whether or not differences in culture or primary language impacted upon website design or content, or whether these sites would follow the same trends as all other sites included in the study.

3.1: Website Selection

As a study examining the websites of all biomedical science research institutes in each of the five countries was not feasible within the constraints of this research project, due to sheer volume, a nonprobability sample was selected using purposive sampling of university-based, research hospital-based and independent research institutes were selected. In order to compile a comprehensive list of research institutes from each country, a range of university based research institutes, state research institutes, independent research institutes and research hospitals were included. Of the university based selections, both research centres and research institutions, but not university departments, were selected to allow for comparisons and to arrive at meaningful results. Selections were drawn from a range of biomedical research disciplines to include biomedical science, biomedical engineering, cancer, neuroscience, biology, regenerative medicine, molecular medicine, genomics, imaging and bioinformatics. The aim was to include approximately 60 websites in the study, roughly divided between the regions of interest.

To arrive at the list of selected websites, eligible research centres and institutes were identified from the Times Higher Education-QS World University Rankings 2009 for the area of life sciences and biomedicine[16]. This yielded a total of 15 sites from the US, 6 from the UK and 3 from Canada. Next, the words "biomedical research institute" were entered into Google, the most frequently used search engine, and the first 100 resulting websites considered for inclusion. Research institutes from the seven Irish Universities were included; particularly those funded under the Science Foundation Ireland Centres for Science, Engineering and Technology (CSET) funding programme. Research institutes funded by the National Institutes of Health (NIH) and the Wellcome Trust in the UK were also included. From these searches, a total of 68 websites were selected for the content analysis. Of that total, 8 websites were selected from Ireland; 22 were selected from the UK; 9 were selected from Canada, 24 from the United States and 5 were selected from Continental Europe[17].

16 http://www.timeshighereducation.co.uk/hybrid.asp?typeCode=423, last accessed March 15, 2009
17 The countries represented in Continental Europe include: Germany, France and Italy.

3.2: Development of Coding Framework

The largest data set collected for this research project was derived through a content analysis of the selected 68 websites. Content Analysis was an ideal method as it allowed for a time-oriented content inventory of the websites that allowed a series of criteria to be registered and then assessed. The work of Trench and Delaney (2004) provided the starting point for the coding framework. Their analysis of the content and user orientation of over 100 Irish-produced websites that present scientific information made use of a coding framework which made a few assumptions. First, it was assumed that "information that is tailored for specific audiences is more likely to be actively received than information that is more generic in character, or that facilitates two-way and many-to-many communication and for linking documents from diverse sources represent distinctive strengths of the Web as a medium of public information." Their study sought to determine the kinds of information given most prominence on Irish science websites; the audiences targeted; how frequently new information was provided; how feedback was facilitated and what external links were made and how. As such, the scoring system used in Trench and Delaney's coding framework gave higher ratings to sites that; gave greater prominence to substantive scientific information; identified to users who the site's intended audiences were; maintained greater frequency of updates; allowed users to interact with the site publishers and content contributors; and pointed users to other sources of information. In using Trench and Delaney's coding framework as the basis of my own, these same assumptions and their influence on scoring apply to my own content analysis.

As the aim of this study was to examine the extent to which biomedical science institutes use the Web as a means of communicating with public audiences, the coding framework was developed to examine sites from the perspective of the general public. As such, websites that tailored their content to the public by using accessible language, explaining scientific terms (either within the text or in a separate glossary), used multimedia tools to aid in scientific illustration, or explicitly categorised content according to particular audiences were favoured. Similarly, sites that contained in-depth information on research projects and findings were ranked above those that provided only general information. Some of the key components that were analysed included;

- whether specific audiences were actively targeted
- the number of non-scientist audiences targeted
- the type of content published
- whether content was published in language accessible to non-scientific audiences
- whether or not opportunities were provided for two-way or many-to-many communication

As with Trench and Delaney (2004), sites that met the above criteria were rated higher than those that did not. For the most part, the framework scored these criteria as yes/no questions, while other questions used several-point scales. It is important to note that the scores obtained by each of the 68 websites included in this study are intended as indications and have been used to identify patterns and trends rather than as precise measurements.

Content analysis criteria were influenced by findings of the literature review and were subdivided into the following five sections;

Attribution and Transparency- evidence of clear and forthright identification of the website publishers to include statements of purpose and institutional information most often contained in an 'About Us' section;

Content and Currency- the type of content made available on the websites to include use of multimedia technologies to further understanding of scientific content and the accessibility of that content to non-scientific audiences, along with a measure of the currency with which that content is updated;

Interactivity and Navigation- the extent to which a website creates opportunities for user interaction (either with the website publishers, content creators or other users) and how well-organised the website is allowing for ease of navigation throughout the site;

Design- the use of effective graphics and text presented in a single style that flows throughout to show consistency. The style should be professional, appealing and relevant to enhance user experience.

Accessibility- evidence that a wide range of potential users have been considered and design, development and editing choices made which attempt to ensure equal access to information and functionality.

Appendix B contains the complete coding framework.

3.3: Website Analysis

Replication

As the Web by its very nature is constantly evolving, the results of this study are indicative of the state of the selected websites during a particular window. As such, replication of this study would yield different results (having revisited the 68 websites several months after analysis was completed, a large number of changes were seen; some websites have undergone a redesign since the content analysis was completed). It was however important to ensure the reliability and accuracy of the data by ensuring the validity of the coding framework structure and scoring system. To do so, my supervisor and I randomly selected 20 websites from a list of more than 100 Irish science websites to pilot the coding. This pilot was conducted over a two week period and the results compared to ensure that the coding framework and scoring system was reliable. As it was found that results of the independent pilots were the same in over 80% of questions, the coding framework was determined to be sound.

The detailed methodology of Lederbogen and Trebbe (2003) was a considerable influence in guiding website analysis. Their systematic examination of the websites of German university and non-university research institutes analysed for "a multitude of design- and content-related elements of Internet sites" through a content analysis. They coded the expression of variables such as service elements on the homepage, navigation elements, and graphic text elements such as icons and tables as available versus not available. Other variables, such as orientation toward target groups, were only coded if the respective target group (academics, students, etc.) was directly listed or mentioned in the navigation menus or elements. The same method was adopted for this study.

The website analysis was carried out between April 1st and April 30th 2009. Each of the websites was viewed more than once with an average of 25 pages viewed on each website for an average total of 1700 Web pages. A total of 92 design and content-related elements of websites was examined in the content analysis. These were collated in a detailed code book and later commented on. The investigation of the criteria was carried out by a single coder by means of visual inspection.

Scoring System

The majority of criteria were graded as either present or not present (ex. link to homepage on all other pages, breadcrumbs, drop-down menus, content dated and author name listed).

Where a website met that criterion, a single point was awarded. While the majority of criteria were simple to code in that a website clearly did or did not meet the required criteria, some were more difficult to code, such as whether or not content was targeted at particular audience groups. In order for this criterion to be coded positive, the respective target had to be explicitly named (target audiences coded for included; scientists, industry, general public, media, postgraduate students, undergraduate students, secondary school students and primary school students) in order to receive the respective point. Other criteria were coded using several-point scales. One example was the presence of several forms of multimedia communications to include graphics, photos, animations, videos, and audio to aid scientific explanation. This criterion could have produced a score up to 5 points. For currency of content, up to 8 points could be scored while targeting a range of audiences could result in a score of up to 8 points. It is for this reason that the 92 criteria coded for amounted to a total possible score of 123 points. The breakdown of points per section is as follows: attribution and transparency- 10 points; content and currency- 67 points; interactivity and navigation- 18 points; design- 17 points; accessibility- 11 points.

3.4: Analysis of Data

Having completed the content analysis, each website was attributed an overall score. The lowest score attributable was three, as three of the questions had a baseline score of one point. As a number of the criteria coded for were those of basic Web design tenets however, the lowest score recorded was 39, making that the baseline for overall findings.

Findings were organised into three categories; overall results; results by country; and results by section. Overall results for each of the 68 websites were used to compile a league table. This can be seen in Appendix C. The highest score given was 100 points, while the lowest score was 39 points. In order to divide overall scores into three ranges for comparison purposes, results were divided as follows; more than 80 points; 60-80 points; and 60 points or fewer. In total, 16 websites scored more than 80 points; 22 websites scored 60 points or fewer; while the majority of websites scored between 60-80 points.

3.5: Survey Questionnaire

Following preliminary analysis of the data derived from the content analysis, a questionnaire to survey communication practitioners in the same 68 institutes was developed to validate the findings. The aim of the surveys was to examine how communication practitioners and scientists view the Web as a way to communicate their work to public audiences in order to further inform the motivations behind those trends emerging from the data and to confirm assumptions that trends were the result of practitioner's intentions.

In order to grasp more fully the results of the content analysis, communications practitioners were asked to comment on the following; the importance of the Web to their institute's external communication policy; to rank in order various means of external communication of which the Web was one; to divulge the percentage of their time devoted to maintaining their website; what purpose they feel the institute website should serve; and whether or not the website targets information to different audiences. A total of 24 questions were asked. The full list of questions can be seen in Appendix E.

Survey data was collected by a questionnaire electronically distributed to those individuals whose contact details were made available on their institute website. All 68 websites were examined to acquire the contact details of a communications officer or similar. As only 45 out of the 68 websites listed a staff member in the area of communications, a total of 45 communications personnel were sent the questionnaire electronically. This methodology was selected due to the geographical spread of the individuals in question. While first person interviews may have resulted in more in depth data, this method was beyond the scope of this project. Surveys were emailed to the aforementioned individuals on March 30, 2010. Within one week a total of 19 responses were received from communication officers. These included 6 responses from institutes in the UK, 4 from Ireland, 5 from the US, 2 from Canada and 2 from Continental Europe. In comparing the results of the content analysis with the results of the survey questionnaire, interesting points come to light that allow for reflective analysis on practice. The complete results of the survey questionnaire can be seen in Appendix E.

4: Findings

4.1: Overall Results of Content Analysis

Upon completion of the content analysis, a total number of points had been allocated to each of the 68 websites. Overall scores ranged from 100 points to 39 points. The mean score was 59 points.

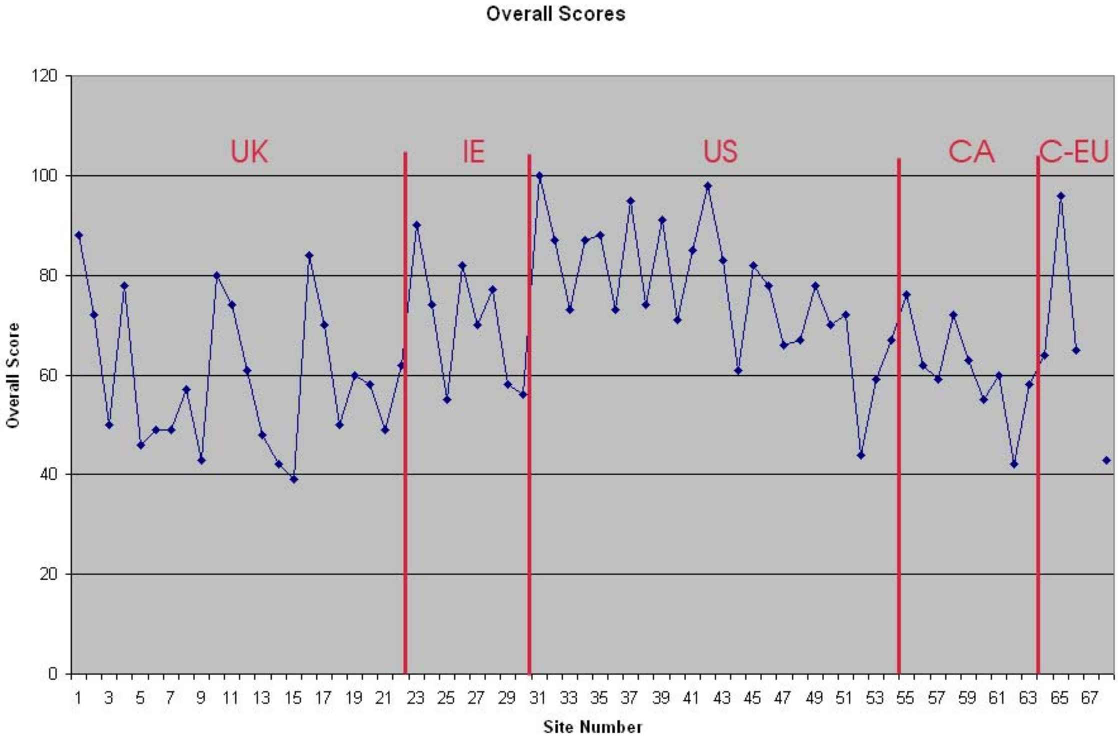


Figure 4.1: Overall scores of all websites, differentiated by region.

In order to analyse the scores, a total score was calculated for each country.

Total Score per Country

Country	Total Score	Avg. Score for Country
United States	1857	77.4
Ireland	565	70.6
Continental Europe	268	67
Canada	547	60.8
United Kingdom	1309	59.5

Table 4.1: Total Number of points and Average points allocated per country

According to total score per country, the US had the highest score, followed by Ireland, Continental Europe, Canada and the UK. This result shows that the sampled websites of biomedical research institutes in the US targeted a number of specific public audiences, provided more content that was written in accessible language suitable to public audiences, contained more extensive information on research being conducted by the institute, presented that information in a more timely manner and more significantly considered the design, navigation and accessibility to an array of users' needs of the websites that any other country examined.

4.2: League Table Ranking

A second level of analysis was conducted by creating a league table of all websites ranked in order from the highest scoring to the lowest scoring. The complete league table can be seen in Appendix C.

Overall scores were subdivided into three ranges, the 22 top scoring sites (with points ranging from 100 to 74); 22 middle scoring sites (with points ranging from 74 to 60); and the 22 bottom scoring sites (with points ranging from 60 to 39).

Examining the number of websites from each country in each range reveals the following;

	Top 22 Sites		Middle 22 Sites		Bottom 22 Sites	
	No. of sites per range	Rank order per range	No. of sites per range	Rank order per range	No. of sites per range	Rank order per range
UK	5	2	6	2	12	1
Ireland	3	3	2	3	3	3
US	12	1	10	1	2	4
Canada	1	4	3	4	5	2
Continental Europe	1	4	2	3	2	4

Table 4.2: Rank order of countries by league table results in each of the 3 ranges

4.3: Comparison of Overall Scores with League Table Ranking

Country	Overall Score Ranking	Top of League Table Ranking
UK	5	2
Ireland	2	3
US	1	1
Canada	4	4
Continental Europe	3	4

Table 4.3: Overall Score Ranking and League Table Ranking for Each Country

Table 4.3 shows that the two means of measuring overall results of the content analysis reveal notable differences. While both the US and Canada maintain the same overall ranking in both measures, with the US maintaining consistently high scores throughout its websites and Canada maintaining consistently average scores. The UK, Ireland and Continental Europe rank differently by overall score than they do by league table. Continental Europe ranked third by overall score but fourth by league table ranking. This was a result of having few high scoring sites, ranking it low in the league table, and an average overall score. Ireland ranked second by overall score but third in the league table ranking. This was the result of having just a few high scoring websites but a high overall score with very few low scoring sites. The UK then had considerably different results by overall score than by league table. While the UK had a small number of websites which earned a high score, ranking high in the league table, the average score for the UK was brought down by a large number of low scoring websites. Unlike the US and Canada, the UK was not consistent in its scoring.

4.4: Overall Findings by Section

4.4.1: Attribution and Transparency

Institution identity and how it is conveyed to users was the first area of enquiry in the content analysis. These criteria looked for evidence of clear and forthright identification of the website publishers to include statements of purpose and institutional information most often contained in an 'About Us' section. Open listing of the funding source for the institute was also noted. This often took the form of logos across the homepage footer.

96% of the websites (65) included an 'About Us' section while 96% (66) clearly indentified the publishers and contained a statement on the purpose of the publisher. This may indicate an awareness of the impact of institutional identity on users' perception of website credibility. Less than 10% of sites contained a statement on the purpose of the website (other than in disclaimer), presumably indicating that the purpose of the site is self apparent and need not be explicitly addressed. Half of sites listed the institutes' principal source of funding, a practice which shows open and honest publication of facts and increases website credibility.

35% of sites have a URL that is the full name of the institute such as yalecancercentre.org and scripps.edu while 31% of URLs were acronyms but contain reference to science such as remedi.ie, meeting Triese et al.'s (2003) standard for domain name recognition and its impact on website credibility. 28% were non-descriptive acronyms such as icr.ac.uk. 4% of sites have a URL that contains unusual characters such as its.caltech.edu/~bi/.

4.4.2: Content and Currency

The Content and Currency section of the content analysis contained the largest number of criteria. Central to this section was examination of the type of content made available on the websites along with a measure of the currency with which that content is updated. The highest weighted features in this section included audiences targeted and timeliness of content. Other features of note included; alerting users to new content; prominence given to information; access to scientific information; and access to scientists.

Audiences Targeted

90% of sites (61) target specific audiences which illustrates both an awareness of potential audiences and efforts to deliver appropriate content. This question was followed by a several point scale question to measure the number of audiences targeted by each website. Eight different audience groups were identified, these included Scientists, Industry, General Public, Media, Postgraduate students, Undergraduate students, Secondary school students and Primary school students. Five websites targeted all of these audience groups. Two of these were in Ireland (Regenerative Medicine Institute, and Biomedical Diagnostics Institute) while the remaining three were all in the United States (Whitehead Institute, Scripps Research Institute and Howard Hughes Medical Institute). These three US institutes were among the top five overall websites and were all independent research institutes. The two Irish sites were university-based research institutes[18]. Of the websites that targeted specific audiences, some included links to those audiences on their homepage as seen below.

(From left to right: Max Planck http://www.mpg.de/english/portal/index.html, Cambridge Neuroscience http://www.neuroscience.cam.ac.uk/, and Whitehead Institute (http://www.wi.mit.edu/ on June 10, 2009)

Only ten websites targeted 6 or more of the audience groups. Most of the websites targeted between two to five audiences with the most commonly targeted audiences being scientists, students (both postgraduate and undergraduate), industry and media.

The five websites which targeted all audience groups provided content which was created specifically for that audience group. Appropriate language, use of a glossary or embedded explanations of scientific terms, use of diagrams, illustrations, video or audio files to further explain scientific research findings and appropriate navigation and design for these (often separate) section of the websites helped to cater content to public audiences in particular. These five websites stand out as examples of best practice for use of the web to communicate science to public audiences.

While nearly all websites targeted content at specific audiences, the vast majority of websites catered to scientific audiences, namely scientists or science students. These sites delivered content that was accessible (in terms of depth, breadth, language and presentation) to scientific audiences only. This likely reflects an institutional decision to use the website as a means of communicating with the scientific community rather than with public audiences.

An examination of events listed on the websites is also indicative of institutional practice. 87% of websites list upcoming events organised by the institute. 43% of these events are geared toward the staff and students of the institute itself while 31% are aimed at the public and encourage public attendance. Many of the public events target secondary school and primary

18 These Irish institutes are funded by a Science Foundation Ireland, a state body which supports communication and public engagement by incorporating an operating budget for both into the institutes structure. REMEDI is a research institute based in my place of work, I had no part however in the development nor maintenance of its website.

school students in particular. Of the websites which listed events aimed at the public, all five top scoring websites were present. The majority of websites that listed public events were in the United States (12). This shows that those websites which used the web as a means of communicating science to public audiences were also engaging in live interaction with public audiences. This indicates a concerted effort on the part of those institutes to engage with public audiences in a range of forms thereby suggesting that an institutional policy, be it formal or informal, for public engagement is in place.

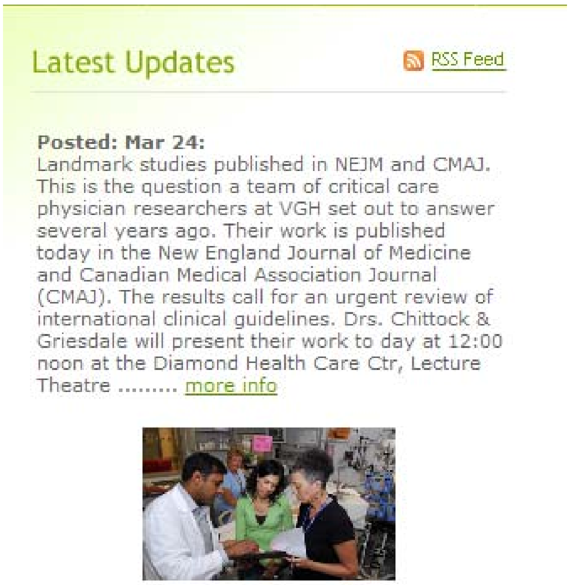
Currency of information- how frequently is new information provided?

Timely reporting of science research news is a key determinant in measuring the quality of science websites (Peterson, 2001). With its ability to rapidly reach a vast audience, websites provide institutes with a powerful medium for broadcasting. This property of the web can be harnessed by institutes to report news. The following findings illustrate some means of drawing users' attention to new content and the extent to which it is being used.

Just over half of the websites date the majority of the content (59%) while 35% name the author of the content. Half of the websites most recent homepage update was less than one month old, while another quarter was within six months indicating that an overwhelming majority of the 68 institutes make an effort to maintain an up to date website. A significant number of websites (52) report on new findings or developments within a News, recent developments or media section. Of these, 41% (28) contained a most recent update that was less than one month old. 21% (14) were between one month and 6 months old, one site had an item 6 months to one year old and 7% (5) were older than one year.

Alerting Users to New Content

82% of websites alerted users to new content on the site. This was mainly done by having a dedicated section on the homepage where new information could be posted, such as the one seen below.



(From Vancouver Coastal Health Research Institute (VCHRI)- http://www.vchri.ca/s/Home.asp Accessed: 25 March 2009).

Sixteen of the websites allowed users to subscribe to an RSS feed. The majority of these feeds were linked to the News page of the site, though some also linked to seminar or event listings, others to more editorial content and some sites offered more than one option of RSS feed. Most of the RSS feed links were on the homepage, but some were only visible on the news or events pages.

In examining the currency of the feed contents, the following was noted. Of the 16 sites with RSS feeds, half (8) were updated more than once per week. Three were updated on a weekly basis, two were updated more than once per month and one was updated monthly. Two of the sites had RSS feeds that were more than two months out of date.

Overall, the majority of websites examined were posting timely updates to content. Some were making use of design techniques that assisted in alerting users to new content while a very small amount harnessed web technologies that could share new content with users in an efficient and effective manner.

Information Provided- what type of information is given most prominence?

The information given most prominence on the homepage was examined and scaled as follows (from lowest to highest); information on the institution, staff and contacts; information on new courses; news and recent events; current research projects; and recent research findings (to include reports). The results were as follows;

Information Given Most Prominence	No.	Percentage
Information on the institution, staff, contacts	10	15%
Information on courses	3	4%
News and recent events	31	46%
Current research projects	5	7%
Recent research findings (to include reports)	17	25%

One quarter of sites featured recent research findings (including reports) on the homepage, while the greatest number featured news and recent events (46%). 15% came in at the lowest point on the scale, highlighting 'about us' and contact information on the homepage. These findings indicate that a large number of institutes (53) use their website to share information reported as news, or to report on research projects, some to include findings. Only a small number of sites are using the web to display "online brochures" as Massoli (2007) found in her study. This tendency toward using the web to communicate more in-depth content is promising.

Of greater significance to use of the web for the communication of science to public audiences however is the extent to which institutions attempt to explain their scientific research to non-scientific audiences. This was analysed by examining whether or not content contained an explanation of scientific terms. Websites that explained scientific terms within the content were seen as attempting to make the content accessible to public audiences whose knowledge of science would not be great enough to understand the material without these explanations. A little more than half of the 68 websites explained scientific terms, mainly within the text, one example of which is seen here.

> "RNAi, a biological process that was identified barely a decade ago, is a natural cellular process that occurs in all cells of all multi-cellular organisms to regulate the translation of genetic information into proteins. This natural process can be manipulated by researchers to switch off specific genes, and there is much research and development work to harness RNAi for therapeutics."
>
> (From: The Immune Disease Institute, Harvard University, http://www.idi.harvard.edu/. Accessed April 13th 2009)

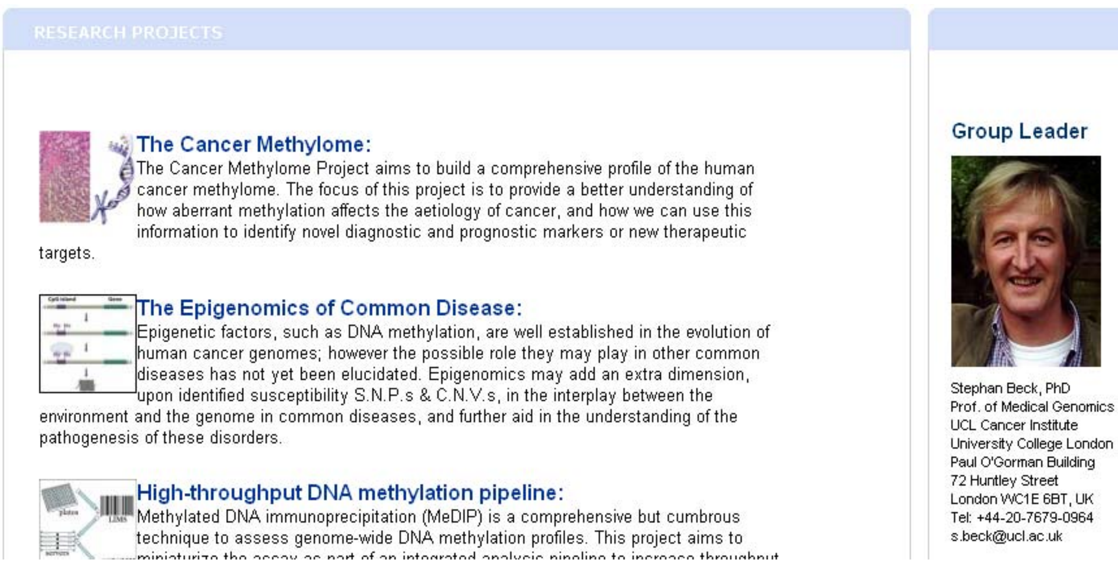
This finding indicates that more than half of the websites considered non-scientific audiences when preparing content for their website. This promising finding suggests that while content may not be targeted directly to specific audience groups, as shown above, efforts are being made by more than half of website developers to create content that can be widely understood.

Access to Scientific Publishing

The extent to which institutes allowed users access to published material was also measured. Of the scientific content provided on the websites, 34% was supported by references or sources. This would allow interested users to gain greater insight into research findings posted on the website and illustrates the extent to which scientific research institutes are "facilitating public access to previously private spaces" as commented on by Trench (2008a). The vast majority of websites (96%) provided a listing of the institute's publications data with 69% allowing access to a publications archive that dated back at least 4 years in most cases. More than half of the publications were available to download, most often through a link to PubMed or a similar resource.

Access to Scientists

Nearly all websites allowed access to scientists directly, either by email (13%) or by office phone number (75%). Contacts were frequently listed on a dedicated page containing a list of all staff, but contact details were often provided on the scientist's project pages, linking the scientist directly to the work being carried out, as seen below. A mobile number for scientists was only made available on one website.



(From: UCL Cancer Institute, http://www.ucl.ac.uk/cancer/research-groups/medical-genomics/index.htm, accessed April 16, 2009)

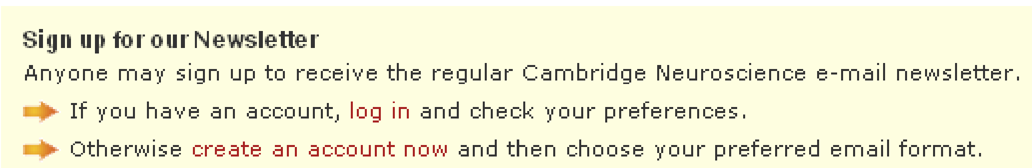
It remains to be seen how frequently the opportunity to directly contact a scientist about his or her work would be taken up by a web users. My own experience would be that the public very rarely attempt to contact scientists regarding research. That an institute would provide this level of access however, at least suggests a willingness to communicate directly with the public.

4.4.3: Interactivity and Navigation

The use of web features that enable interactive communication enhances content to improve user experience by placing greater control in the hands of the user. Well planned navigation features ensure that a website is easy to use and allows for a positive user experience both of which should be a principle consideration of an institute when constructing a website.

This study found that 35% of websites included a sitemap, 71% had a search engine facility, 68% used drop down menus and 34% list breadcrumbs to aid navigation through the website's pages.[19] Nearly all of the websites (91%) included a link to the homepage on every page of the website and made use of a main navigation menu that remained constant on each page. The page title appeared in the browser's top window bar in 62% of websites. Few websites contained broken links (22%). Overall, the majority of websites made effective use of navigation features, thereby enabling a positive user experience.

Interactivity features however were found to be lacking on the majority of websites. Just over one quarter of sites (28%) contained a subscription newsletter, similar to the one seen below while only two sites included a discussion board and/or a message board.



(From: Cambridge Neuroscience, http://www.neuroscience.cam.ac.uk/ accessed April 2, 2009)

Less than 10% of websites surveyed users for feedback. None of the websites contained opinion polls nor provided any results of evaluation of its effectiveness or impact. These

19 After the story "Hansel and Gretel" by the Brothers Grimm, breadcrumbs are links displayed across the top of a web page listing the most recently visited pages so the user can quickly jump back to one.

findings indicate that one of principle uses of the web as a platform for communication, interactivity, is being underused by the biomedical research community.

4.4.4: Design

Like good navigation, effective website design has a significant impact upon users' experience of a website. As Fogg (2002) showed, good design can impact a users' willingness to accept information contained on a page. The following findings show that a good level of website design standards is being met by the majority of the 68 websites.

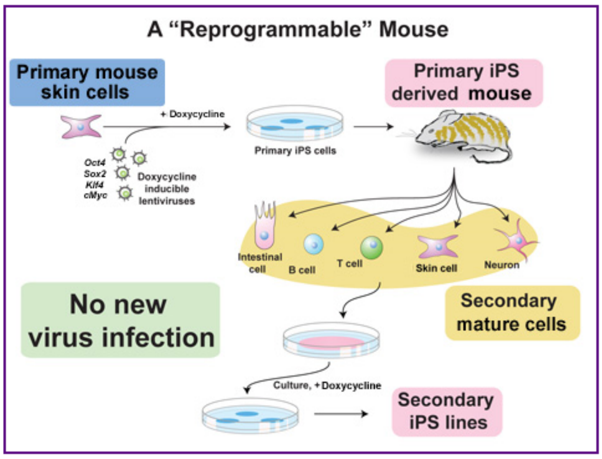
Almost all of the site designs were consistent throughout (91%). 35% of websites used colour to enhance the site; this was determined by whether or not a site used colour to differentiate between areas of the website thereby helping to orient users within the site, as seen below. 85% of all sites had a fluid layout[20]. Half of the websites were designed so that page content could be viewed in its entirety in the browser window, while the other half made use of long pages of content which required scrolling. 75% of homepages could be viewed on one screen while the other quarter required scrolling. 97% of homepages were easily recognisable as the homepage, while 93% of homepages had links to all significant areas of the site. Only 4% of homepages contained a 'tagline' that accurately and succinctly outlined the purpose of the site. An institute logo was consistently placed on the pages of 94% of websites. 88% of websites placed important content in the top/centre of the page.

20 Fluid layout is a design technique which ensures that the varying resolution settings of users will not negatively impact on the appearance of the website. The alternative is fixed layout which often results in sections of the site being lost from view due to small resolution settings on a users monitor.

(From: the Regenerative Medicine Institute, www.remedi.ie, accessed April 21, 2009)

The websites were analysed for use of graphics, photos, animations, video and audio content that aided scientific illustration. Like the question included in the content section on explanation of scientific terms, this question looked at the extent to which institutes used multimedia web features (as opposed to text) to explain scientific content. Like the content question before it therefore, these findings are indicative of the measure of effort institutes are making to ensure that scientific content is accessible to a wide range of audiences, particularly public audiences.

This was a scaled question, with the websites scoring one point for each form of illustration to a total of five points. Only five websites made use of all five forms of illustration. They were the Regenerative Medicine Institute (Ireland), Whitehead (US), Institute of Systems Biology (US), Howard Hughes Medical Institute (US) and Max Planck (C-EU). Three out of the five were amongst the top five scoring websites overall. Video content on these sites ranged from interviews with scientists, to short films explaining scientific concepts; audio content mainly took the form of podcast interviews; animations, photos and graphics were used on project pages to illustrate research results and findings. Examples from the Whitehead Institute can be seen below.



A night in the life of Whitehead
Behind the scenes one late evening at the Institute
[read more]

Stem Cell Video

Whitehead Institute Podcast

Enjoy a conversation with a Whitehead researcher on the latest biomedical research. Each podcast features an interview with an expert on a particular topic.

(From: the Whitehead Institute, http://www.wi.mit.edu/index.html, accessed April 18, 2009)

The majority of websites scored 2 on the scale for this coding feature, with the most commonly used aids being graphics and photos. 17 of the websites did not use any multimedia features to explain scientific content. These findings indicate that the web's ability to deliver content in a range of mediums is being underutilised and that few websites are using multimedia features to improve their websites accessibility to public audiences.

4.4.5: Accessibility

Use of easily readable background and text colours and the ability to increase text size ensures access to users with visual impairments and learning disorders. Text only options and the ability to view content without high level technology allows access to those with low broadband speeds and dated computer software. Accessibility is about considering the widest range of potential users and ensuring access to all. The following findings show that basic accessibility features, such as browser compatibility and considered background and text colour use was present in the vast majority of sites, other features such as text size increase and text only format are lacking and require more greater implementation.

All of the websites could be viewed using a standard browser and did not require special and/or high level technology. 6% of websites were available in a text-only format; more than half of the websites contain equivalent text links for graphics (62%), while very few websites provided a facility to increase text size (5). All of the websites were designed with background and text colours that were easy to read. Little over half (56%) of sites presented multimedia files in an accessible format. Only 4% of websites impaired the user's ability to use the back button. 97% of sites had a navigation system that was constant throughout the site.

4.5: Five highest ranked websites overall

This section provides a description of the websites of the five highest ranking sites in the sample. While overall findings can provide an indication of trends in the type and currency of content presented in the sample websites, use of interactivity features and choice of navigation tools, design features and consideration of accessibility, this section elaborates on the specific features of the top-scoring websites in order to present a clear depiction of those websites which best use the web to communicate science to public audiences.

In presenting greater detail on these selected five websites, other features of the institutes can be considered, principally the scale of the institute but also the type of organisation the website represents (university based, state, or independent research institute) to identify patterns and trends that may have an influence over the nature of the institute website.

A sample of the five highest scoring websites was selected in order to present a range of the types of websites allocated significantly high scores.

The top five websites overall are as follows; The Whitehead Institute for Biomedical Research (100 points/US); Howard Hugh Medical Institute (98 points/US); Max Planck Society (96 points/C-EU); Scripps Research Institute (95 points/US) and Mayo Clinic Research Hospital (91 points/US). All five of the top scoring sites are independent research institutes. Four out of five are from the US.

These websites, in being the highest overall scoring websites out of the samples of 68 institutes, demonstrate excellent examples of ways in which the web can be used by biomedical research institutes to communicate science to public audiences.

Website Ranked #1 with a score of 100 points: (http://www.wi.mit.edu/) The Whitehead Institute for Biomedical Research is an independent research institute affiliated with the Massachusetts Institute of Technology (MIT) when it comes to teaching and academic appointments, but autonomous from the university. The website is independent from MIT.

Scale of the institution: At the time of coding, the website stated that the institute had 25 principal investigators (Members and Fellows) and more than 200 visiting scientists, postdoctoral fellows, graduate students and undergraduate students from around the world.

Features of the website: This website targeted content to a wide array of audiences, and provided links from the homepage for the following; scientists; postdocs; students; educators; media; alumni; faculty and staff; and board of associates. A significant amount of content was then provided which was tailored to each of these audiences, using appropriate language, and explaining scientific terms within the text, while supplementing written material with a range of multimedia features which further explained the science. Based on the website content, public engagement appeared to be an important focus of the institute, as it provided a breadth of content for teachers, students (high school and primary), as well as the general public. Events were listed which were held regularly and which both invited, and catered to, the public which illustrated that face-to-face engagement, along with online engagement, was part of the institutes work.

Specific research topics were highlighted on the homepage, specifically Cancer, MicroRNA and Stem cells, at the time of coding. These links brought users to pages loaded with content on the topic, which was delivered in language accessible to non-scientists and effectively supplemented with video and audio files with provided greater detail into the three subject areas.

The site made effective use of web technology. Research content was supplemented with audio and video files, illustrations, animations and images with strong effect.

Credibility of websites content was aided by the making available of a considerable amount of information through the website by providing an extensive publications archive to interested users. Open information sharing was further exhibited by publishing of the organisation of the institute and the clear listing of funding sources.

The site was kept up to date, with news stories generated almost daily. Users were given the opportunity to subscribe to an RSS feed to receive updated content.

The design of the site was fluid and user friendly, with a number of navigation features that made the site easy to use. Accessibility had been considered.

Website Ranked #2 with a score of 98 points: (http://www.hhmi.org/) The Howard Hughes Medical Institute is a non-profit research institute founded through philanthropic donations.

Scale of the Institution: At the time of coding, the website stated “Our 355 investigators include 13 Nobel Prize Winners and 124 members of the National Academy of Sciences. Hughes laboratories, found at 71 distinguished U.S. universities, research institutes, medical schools, and affiliated hospitals, employ nearly 700 post docs and provide training opportunities for more than 1,000 graduate students each year.”

Features of the website: This website contained a significant amount of content dedicated to reporting research findings in language that was accessible to a non-scientific audience. A visually appealing ‘top stories’ application on the homepage directed users’ attention to latest findings. The application linked to the complete story, and provided details on the researcher(s) behind the story.

The news section of the website was extensive, with stories divided into the following categories; top stories, research news, science education news, and institute news. News items contained links to download the research publication to which it referred.

The site used RSS extensively and gave users the option of subscribing to an e-newsletter. This publication was supplemented with ‘online extras’, multimedia files to enhance explanation of the science content.

There was an extensive public outreach portion to the website called ‘Cool Science’ with resources for students and teachers. An ‘Ask a Scientist’ feature allowed users’ to ask researchers questions. One question was featured at the time of coding, with an archive listing previously answered questions. Also included in this section were links to ‘homework help’; ‘science fair project’; ‘careers in science’; and ‘personal health’. Each contained a series of links of the subject. Also listed on the website were events run specifically for the public.

Content was available in Spanish as well as English.

As a number of the institutes’ researchers were based in other universities, the user was at times navigated away from the main site.

Website Ranked #3 with a score of 96 points: (http://www.mpg.de/english/portal/index.html) Max-Planck Society is an independent research institute, with multiple locations throughout Germany.

Scale of the Institute: At the time of coding, the website stated "there are 76 institutes and 3 additional research facilities employing approx. 13,000 employees (as of 1.01.2008). Included in this are approximately 4,700 scientists and 11,850 student assistants, fellows of the International Max Planck Research Schools, doctoral students, postdoctoral students, research fellows and visiting scientists (as of 1.01.2008)."

Features of the website: The depth of this website was extensive; it contained a significant amount of information on the research, groups, projects, and staff that make up this society.

An extensive amount of information was made available on the research projects underway by Max Planck researchers, with access provided to a breadth of research documents and publications.

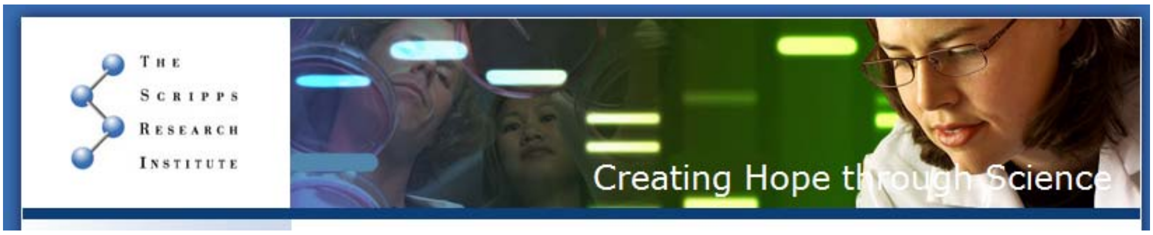
A database of science videos contained a significant number of short documentaries, each highlighting the work of a different research project. The database was searchable by research area with a selection highlighted at the time of coding. These videos presented the science in clear, accessible terms.

It was however not easy for the user to trawl through the site to find content. When seeking staff pages for example, it took a number of clicks before I reached the page I was after. The way in which sections were labelled was not always clear, further complicating access to particular information.

The site was very up to date, with press release issued nearly every other day. It was easy to find new content. A great deal of content was dated and authored. The site catered to a number of audiences; alumni; applicants; journalists; scientists; and teachers and pupils. A menu on the homepage provided a link for all of these audience groups to draw users to content designed for them specifically.

The navigation would have been enhanced by breadcrumbs, especially considering the depth of the site.

Website Ranked #4 with a score of 94 points: (http://www.scripps.edu/e_index.html) The Scripps Research Institute is an independent biomedical science research institute with two locations, Florida and California. (Labelled No. 37 in Coding Framework)



Scale of the Institute: At the time of coding, the website stated "staff numbers some 2,800, with 289 faculty members, nearly 815 postdoctoral fellows, 235 graduate students, and over 1,500 technical and administrative support personnel."

Features of the website: This institute had two locations, Florida and California and while the two were presented on the one site, a change in design colour differentiated between them.

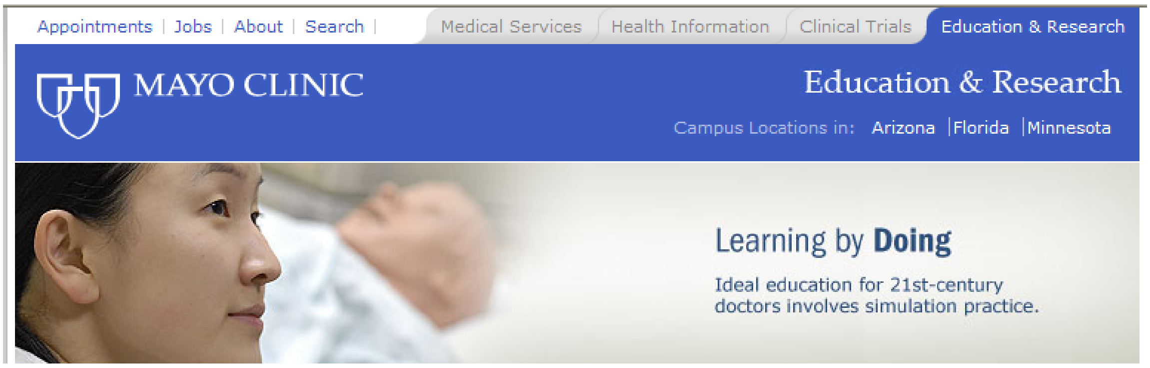
The site acknowledged a range of audiences, providing a significant outreach programme for school students and teachers. Events were listed that catered to the public.

The site was very up to date, with press releases issued almost daily. Latest news items were highlighted on the homepage and articles were written in accessible language, explaining any scientific terms used. The press releases included links to the research publication to which it referred. Users were given the option to subscribe to both a monthly newsletters and to a weekly 'news and views' email highlighting new research findings.

Research information was presented first by disease (ex. Alzheimer's, Autism, Blindness, Breast Cancer, followed by Centre and finally department. This made it very simple to find information on particular topics. Placing the disease listing at the top of the page showed that the Institute was considerate of public audiences. Information on the disease pages was accessible, while scientific content on department pages was dense. While some terms were explained in the text on these pages, the language was complex for non-scientists.

The design of the site was well laid out, though the drop-down menus were difficult to use. Accessibility does not appear to have been considered by the designers.

Website Ranked #5 with a score of 91 points: (http://www.mayo.edu/) Mayo Clinic Research Hospital is an integrated, not-for-profit group practice with a section of its site dedicated to education and research.



Scale of the Institute: At the time of coding, the website stated that "Research Personnel include Physicians and medical scientists (368), Temporary professionals (555), and Allied health personnel (2,239)."

Features of the website: Only the education and research pages of the greater Mayo Clinic website were examined, though design and navigation of this section of the site were identical to that of the parent site (one exception to this was the events listing which was on the parent site).

The website contained a significant amount of information on the various illnesses and diseases that encompassed the clinic's research areas. Research areas were presented in an extensive alphabetised list by disease or condition. These links brought the user to a page with an overview, list of research projects underway in the disease area (which included a short description) and information on the researcher involved in the project. The content was written in accessible language, geared as much toward patients as it was to scientists. A large number of images, animations and films were included on the research pages to support instruction.

'Discovery's Edge', the institute's monthly magazine was featured on the homepage and contained a number of stories on ongoing research areas. The articles were written in accessible language and supplemented with research images. Users were given the option to subscribe to the publication by email or by RSS.

A unique feature was the 'Mayo Clinic News Blog' which allowed users to access video and audio excerpts featuring Mayo Clinic physicians and researchers providing context for stories about their research and other health and medical news.

The site was moderately up to date (the most recent news item being one month old) and news items were dated and named.

The site catered to a few different audiences, though little could be found for students (secondary and primary).

Navigation and design were both effective, the site was easy to navigate.

Observations

Four of the five top sites are those of large scale research institutes, each with over 1,000 staff members. The exception when it comes to scale is the top ranked site, the Whitehead Research Institute which has a staff of only 225.

As outlined above, the five websites which ranked the highest overall targeted a wide array of non-scientific audiences and published content on their websites that had been specifically created for these audiences, making use of language that was accessible to non-scientists, presenting scientific information in simplified terms or supplementing scientific terminology with explanations. Each of the websites provided both text and multimedia content which explained science concepts in detail for non-scientists audiences. Public events listed on these websites illustrates the fact that the website is just one means used to engage public audiences, suggesting that a policy is in place in the institutes to educate or inform the public about scientific research being conducted by its staff.

In addition to these direct efforts to engage public audiences, the above five websites made use of interactivity features which encouraged dialogic communication, either from scientist to scientist or user to user. This illustrates an effort on the part of these five institutes to harness the web's unique properties in order to enhance the experience of users visiting the website.

While communication with a range of public audiences is clearly found on these five websites, additional features of note include the use of effective navigation features which made use of the sites (including those sites which were complex and contained a vast amount of pages) easy to use and orient within. Well thought-out design which was consistent throughout the websites in terms of layout, colour and style and made effective use of colour to differentiate sections of the website were present to help the user to navigate through the websites. Finally attention to accessibility features ensured that a range of users would be able to use the site without difficulty.

All of these factors combined to create websites that considered public audiences and could provide a non-scientist with an informative, interesting and engaging online experience.

4.6: Findings by Country in order of overall scores

4.6.1: United States

Overall scores

The highest scoring website within the US sites scored a total of 100 points. This was also the highest scoring website overall. The lowest scoring website within the US sites scored a total of 44 points. Overall the US website's average score was 77.4 points, which placed the US 1st overall.

Standing in the League Table

The US had 12 sites within the Top 22 websites in the league table. This was the largest number of websites within the top range of the league table, and more than twice the number of sites as the next highest country (the UK with 5 sites). The US had 10 sites within the Middle 22 sites in the league table and 2 within the bottom 22 sites. This was the smallest number of websites within the bottom 22 sites in the league table, tied with Continental Europe which also had 2 sites in this range.

The US overall standing in the top of the league table was 1st.

Observations

The US websites scored consistently high, topping both the league table and the overall scoring. With a high number of high scoring websites and few low scoring websites, the US websites out ranked all other countries. Four out of the top 5 scoring websites overall were from the US. On a whole, US websites published clear and forthright information about the institutes, clearly indentifying the publishers of the websites and authoring the majority of content. This level of transparency aids the US sites in maintaining a high level of credibility. The high score of the US websites indicates that a large number of US websites considered public audiences when preparing content for the website and targeted a range of audiences directly. Text content contained explanations of scientific terms and multimedia materials were also provided with further aided illustration of scientific concepts. US websites were allocated the highest score for interactivity and navigation when compared to the four other countries. Effective navigation in particular was used in the vast majority of US websites, easing the user experience. While a number of websites made use of interactive features, more than any other country, this number was still low. Design of the US sites was well considered overall, with effective use of colour, consistent layout and style and fluid layout found in almost all sites. The US also scores the highest number of points overall in the accessibility section when compared to the other countries. This likely indicates a greater awareness and observance of best practice in the inclusion of accessibility features on a national scale.

Highest scoring website in the US sample

Highest Scoring Site in the US Sample

Website ranked #1 overall with a score of 100 points: Whitehead Institute for Biomedical Research- http://www.wi.mit.edu/

As the highest scoring websites overall, notes and comments on the Whitehead Institute website were included in the earlier section.

4.6.2: Ireland

Overall scores

The highest scoring website within Irish sites scored a total of 90 points. The lowest scoring website within the Irish sites scored a total of 55 points. Overall Ireland's website average score was 70.6 points, which placed Ireland 2nd overall.

Standing in the League Table

Ireland had 3 sites within the Top 22 websites in the league table; 2 sites within the Middle 22 sites in the league table and 3 within the bottom 22 sites. This placed Ireland third overall within each range of the league table.

Observations

With three out of Ireland's eight websites placing within the top 22 sites in the league table, Ireland scored a high average for a small number of institutes. Ireland's lowest scoring website received 16 points more than the lowest scoring overall websites. Irish websites contained a greater amount of attribution and transparency content that any of the other countries. Forthright publication of the funding agencies behind each of the websites, clear publication of the institutes aims and authorship attributed to content on the websites all featured. By web standards, the Irish websites included more information that would contribute to user satisfaction with website credibility than any other country. Irish websites also received the highest number of points for content and currency when compared overall to the other countries. On average, Irish websites provided more in-depth, timely and public audience targeted content than the other countries, scoring .5 point more than the US. This resulted from the fact that the Irish websites consistently performed well in this section. Irish websites, though few in the sample, consistently targeted a range of public audiences and catered content directly to them, demonstrating efforts to explain scientific content in terms that would be accessible to non-scientific audiences. Ireland did not perform well however in the either interactivity or navigation. Navigation features were lacking which would have yielded an easier user experience. Interactivity features were significantly lacking, demonstrating a missed opportunity to engage users in dialogic communication. Ireland did however score the highest number of points in the design section with a large number of its websites demonstrating consistent layout and styling, effective use of colour and considered use of multimedia content to aid scientific illustration. Accessibility features were lacking from Irish websites on a whole.

Highest scoring website from the Ireland sample

Highest Scoring Site in the Ireland Sample

Website Ranked #6 Overall with a score of 90 points: The Conway Institute- http://www.ucd.ie/conway/

As one of the top ten scoring sites, this website contained a high number of features included in the coding framework. The site contained a considerable amount of content, both on the institute itself and on active research programmes. Research information was presented in accessible language and explained scientific terms within the text.

The institute was aware of and catered to a number of audiences, including public audiences and both secondary and primary school students. The site contained evidence of public engagement activities; a number of public events were listed which were geared to a public, non-specialist audience.

The design of the site was well executed; the site was up to date and easy to navigate.

4.6.3: Continental Europe

Overall scores

The highest scoring website within Continental Europe's sites scored a total of 96 points, the third highest ranking website overall. The lowest scoring website within Continental Europe's sites scored a total of 43 points. Overall Continental Europe's website's average score was 67 points, which placed Continental Europe 3rd overall.

Standing in the League Table

Continental Europe had 1 site within the Top 22 websites in the league table; 2 sites within the Middle 22 sites in the league table and 2 within the bottom 22 sites. Continental Europe tied with Canada for having the lowest number of websites in the top 22 range as well as the highest in the bottom 22 range.

Continental Europe's overall standing in the top of the league table was 4th.

Observations

With just one site at the top of the league table, Continental Europe ranked low overall according to this measure. Measured by overall score however, Continental Europe finished in 3rd place. The overall score received by Continental Europe was increased by the very high scores received by its highest ranking websites. On a whole, the Continental Europe websites achieved average scores as compared to the other countries. The websites were neither overly lacking nor overly impressive in the majority of sections. Attribution and transparency features were lacking from the Continental Europe websites, which could lead users to call the credibility of some of the websites into question. Publication of clear authorship and identification of the institute responsible for the website would resolve this issue. Content and Currency scores placed Continental Europe websites in third overall. While some of the websites, including the highest ranking website amongst the Continental Europe sample which also placed in the top five scoring websites overall, contained a significant amount of content that had been created for specifically targeted websites, and that sought to make information accessible to non-scientific audiences, other websites catered solely to the scientific community and made no effort to use the web as a means of communicating with public audiences. Continental Europe websites finished second overall, after the US, for interactivity and navigation features. Effective navigation and some use of interactivity features (again, in the highest scoring website) demonstrated consideration of the web's unique properties. Design and accessibility scores were both average indicating some though not enough consideration of these web elements.

Highest scoring website from Continental Europe sample

Highest Scoring Site in the Continental Europe Sample

Website ranked #3 overall with a score of 96 points : Max Planck Society-
http://www.mpg.de/english/portal/index.html

As one of the highest scoring websites overall, notes and comments on the Max Planck Society were included in the earlier section.

4.6.4: Canada

Overall scores

The highest scoring website within Canada's sites scored a total of 76 points. The lowest scoring website within Canada's sites scored a total of 42 points. Overall, Canada's website's average score was 60.8 points, which placed Canada 4th overall.

Standing in the League Table

Canada had 1 site within the Top 22 websites in the league table, tying with Continental Europe for the lowest number of sites in this range; 3 sites within the Middle 22 sites in the league table and 5 within the bottom 22 sites. Canada had the second highest number of websites at the bottom of the league table.

Canada's overall standing in the top of the league table was 4th.

Observations

With average or below average scores across all nine of Canada's websites, not one website stood out as being high scoring. Canada did not score well in any of the sections, but was the only country to rank lowest overall in three sections. The score received by Canada for the content and currency section pulled down the country's overall score considerably. Like the UK, Canadian websites on average contained fewer than half of the features coded for in this section. Little effort was made on the part of the Canadian websites to publish forthright information on the institutes or their funding agencies which might lead users to call the credibility into question. This issue could be resolved by clearly publishing the identity of the website publisher and making information about the institute more readily available. Content and currency in particular was found to be lacking. While one website targeted seven out of the eight specific audiences coded for, the Canadian average was just 3, with more sites providing content suitable to scientific audiences than public audiences. Information was frequently out of date on the Canadian websites and little effort was made overall to provide content that was accessible to non-scientific audiences. Canada scored lowest overall for interactivity and navigation, demonstrating very few examples of good practice in effective navigation features and no use at all of interactive features that would allow for dialogic communication. Design was poor in the majority of Canadian websites, and seemed to be significantly less considered than that of the websites of other countries. Finally accessibility scores were the lowest overall for Canada, in marked contrast to its southern neighbour who demonstrated consistent adherence to the inclusion of these features.

Highest scoring website from Canada sample

Highest Scoring Site in the Canada Sample

Website ranked #20 overall with a score of 76 points: Genome Quebec Innovation Centre- http://www.genomequebecplatforms.com

There was a significant amount of information on the field of genomics, its history and the impact it has had on human health included on the site. The language used to explain terms, etc. was very accessible. The site was clearly written with the non-scientist in mind.

The site was kept up to date with press releases that were dated and named and events listings, some of which were geared for public attendance.

The Geee! In Genome project deserved particular mention, a public event, it was held annually and aims to make genomics understood and accessible to public audiences.

The Geee! In genome
On January 15, 2009, the interactive exhibition The Geee! In genome officially opened at the Musée minéralogique et minier de Thetford Mines. The exhibition will be presented until April 26.

- Press release
- Web site

(From: the Genome Quebec Innovation Centre- http://www.genomequebecplatforms.com, accessed April 18, 2009)

4.6.5: United Kingdom

Overall scores

The highest scoring website within the UK sites scored a total of 88 points. The lowest scoring website within the UK sites scored a total of 39 points. This site was also the lowest scoring site overall. Overall the UK website's average score was 59.5 points, which placed the UK 5th overall.

Standing in the League Table

The UK had 5 sites within the Top 22 websites in the league table; 6 sites within the Middle 22 sites in the league table and 12 within the bottom 22 sites. This was the largest number of websites within the bottom 22 sites in the league table; the country above it had fewer than half as many sites in the range.

The UK overall standing in the top of the league table was 2nd.

Observations

With five sites at the top of the league table, the UK ranked very high overall according to this measure. Measured by overall score however, the UK finished in last place. The overall score received by the UK was brought down by a considerably high number of low scoring websites. UK sites scored lowest overall in attribution and transparency features. Website credibility could be called into question by the lack of authorship, clear identification of the publisher and institutional information, including funding agencies. The UK received the lowest number of points for the content and currency section with an average of just 26 points out of a possible 67. This score received pulled down the country's overall score considerably, with websites on average containing fewer than half of the features coded for in this section. Just a small number of UK websites targeted content at public audiences, with far more focusing their content on provision of information for those within the scientific community. A number of websites contained little up to date information and many of the websites provided just the minimal amount of institutional information as opposed to in-depth scientific information. Some use of effective navigation features was found on UK sites however which illustrates consideration of the user experience. Only three UK websites contained an interactive feature. While some of the UK websites made effective use of web design tenets, a larger number failed to make use of consistent layout, effective use of colour or styling to enhance user experience. An average score in the accessibility section placed the UK in second compared to the other countries. This was the highest placing received by the UK out of the six sections.

The Highest scoring website in the UK sample

Highest Scoring Site in the UK Sample

Website Ranked #8 Overall with a score of 88 points: The Sanger Institute- http://www.sanger.ac.uk/

The Sanger site was very dense with a significant amount of content, both about the organisation and its staff as well as its research. The research pages were heavily populated with information, though there was very little, if any, effort made to explain the research in simplified terms, the site developers were clearly seeking to communicate with other scientists on these pages.

Significant effort was made to communicate with the public in a designated section of the website which outlined the institute's public engagement programme. This section of the site provided users with opportunities to engage directly with staff through podcasting; outlined days during which the public can visit the institute; and included online resources such as animations explaining 'how the human genome was sequenced'.

The News section of the website was both timely and densely populated. There were press releases issued on a near daily basis; all were dated and authored with links to the references.

Also of depth was the links section of the site which included hundreds of links divided into general links and those pertaining to the institute's areas of research. The links provided included; academic organisations; professional societies; funding agencies; professional tools and databases; and job listings through science publications.

A unique element of the site was inclusion of all staff theses, available to read on the site.

Navigation was simple and consistent. The site was enhanced with images, all of which were appropriate to the page content. New information was highlighted on the homepage and users were given the option of subscribing to an RSS feed of press release and new research findings.

4.7: Survey Questionnaire Findings

4.7.1: Overall Results

Survey questionnaires were sent to the 45 communications staff named on the websites out of the 68 institutes included in the study in order to ascertain the motivations behind and potential root causes of the trends and patterns which emerged from the content analysis. In surveying the personnel in the institutes largely responsible for external communications, it was possible to gain a deeper understanding of the information coming forth through the data. Complete results of the questionnaire can be found in Appendix E.

All 19 positive respondents to the survey reported that they felt their institute's websites was very important to external communication.

When asked to rank a list of means of external communication according to their importance in the institute, more than half (13) replied that the website was the most important. Press releases followed, with 3 respondents selecting that option while 1 respondent selected printed or online newsletters.

Time allocated to management of the websites was divided into the following possible responses; 10%, 25%, 50%, 75% or 100% of the individuals' time. The majority of respondents (10) admitted to spending just 10% of their time maintaining their website. This was followed by 3 respondents who spend 25% of their time maintaining their website, and 2 respondents sending 50% of their time.

11 respondents reported that their institute had a member of staff dedicated to maintaining the website.

11 respondents reported that their institution involved research staff in creating content for the website. Of them, 70% provided research staff with guidelines for Web content creation. Eight respondents reported that they provide access for research staff to populate content on the website themselves, while 10 did not. Of those who provided access, 6 reported that they edit the content posted by research staff, while 7 do not.

When asked whether or not their research institute provides training to assist communications personnel in populating the website, the following forms of training were reported to be available; science writing for the web (3); use of the content management system (11).

14 respondents reported that their institute allows research staff to maintain a separate Web page or website for their own research group. None of those 14 edited the content posted by research staff on these external sites.

When asked what purpose they felt an institute website should serve; respondents reported the following; to provide contact details, general institute information (13); to provide information on education and job openings (10); to provide news and upcoming event information (13); to provide information on current research (16); to provide detailed information on research (to include reports) (5).

15 respondents reported that their website targets different audiences. When asked what audiences are catered for, the following was reported; other scientists (16); industrial partners (8); the media (15); the general public (17); postgraduate students (13); undergraduate students (9); secondary school students (6); primary school students (4); patients (4).

Respondents were asked how frequently they updated information on the website. They reported the following; daily (8); weekly (3); a few times per month (3); monthly (0); a few times per year (1); annually (0).

When asked if their websites supports information on research projects with reference or sources, 10 respondents reported that they did while another 5 reported that they did not. When asked to report the types of sources they provide, the following was reported; abstract of research paper (1); complete research paper (0); link to research paper in PubMed or similar (1); research images (1); list of research paper sources (5); other (2) to which the following comments were made, “summaries of research written specifically for our website, with sources”; and “all of the above, depending on the article.”

5 respondents reported that they provide access to research publication through the website while 10 do not.

When asked if they publicise grant information on the website 11 reported that they did while 4 reported that they did not.

15 respondents reported that they feel it is ‘very’ important to keep the institute website up to date.

When asked if they have reservations about posting information on their institute website, 6 reported that they did. Asked to comment on the reason behind their reservations; respondents replied; “animal research”; “it depends on the nature of the information”; and “given the nature of the industry-academic collaboration, there is Intellectual property sensitivity around some emerging research areas.” 12 respondents reported that they did not have reservations about posting information on their website.

10 respondents reported that they felt their institute websites was a good representation of the research conducted in the institute, while 5 reported that the website somewhat represented the institute. Additional comments posted included the following; “we are beginning our process to redesign our research website”; “our website is sadly out of date, so we are currently recruiting for a communications officer to take on this responsibility for us. Once hired, the first priority for this person will be to totally revamp our website”; “donors and potential donors are important audiences for our website, as well as members of our Board of Trustees”; “the website was recently updated to reflect the dynamic nature of research within the Institute. There is not a full-time dedicated resource to the site, in an ideal funding scenario this would be the case! The site updates lie within the E & O team and updates happen on a bi-weekly basis. We believe the website acts as an opportunity for many of our stakeholders to find out more about us, but also as a method to get in touch with us. We don’t publish long detailed information on the site, rather smaller”; “while we know how important our website is, staff resources prevent us keeping it as up to date as we would like. We know our website could be improved.”

4.7.2: Questionnaire results by country

US

5 communications personnel responded from US institutes.

Of them, all 5 reported to feel that their institute's website was 'very' important to external communication. Three out of 5 ranked the website as the most important means of external communication, while two ranked press releases as the most important. In the comments for this question, one US communications personnel replied the following, "1. Press releases. 2. Website. 3. Electronic newsletters. 4. Educational events for science writers/journalists."

1 out of 5 US respondents reported that they spent 50% of their time maintaining their institute's website, 1 reported spending 25%, while the remaining three reported to spend 10%.

All 5 respondents reported that their institute had a member of staff dedicated to maintaining the website.

All 5 respondents also reported that their institute involved research staff in creating content for the website. Of these, all five reported that their institute provided research staff with guidelines for web content creation and that their institute gave research staff access to populate the website themselves. 2 reported to edit that content prior to publication, while three reported that they did not.

1 US respondents reported that their institute provided training for 'science writing for the public' while 5 reported the availability of training in 'use of the content management system'.

When asked if their institute allowed research staff to maintain a separate website, all 5 US respondents reported that they did. None of these reported that they edited the content of these external sites.

In response to the question of the purpose an institute website should serve, US respondents reported the following; to provide contact details (2); to provide information on education and job openings (3); to provide news and upcoming event information (4); to provide current information on research (5); to provide detailed information on research (to include reports) (3).

All 5 of the US respondents reported that their institute targeted information to different audiences. Audiences reported as targeted included; other scientists (3); industrial partners (2); the media (5); the general public (5); postgraduate students (5); undergraduate students (5); secondary school students (3); primary school students (1); patients (3).

When asked how frequently they updated information on the website, 3 US respondents reported 'daily', while 1 reported 'weekly.'

All 5 US respondents reported that their website supported information with reference or sources. Of the three that reported 'yes', 2 reported that a 'list of research paper sources' was provided. 2 respondents reported 'other' and commented: "summaries of research written specifically for our website, with sources" and "all of the above, depending on the article." 2 respondents reported to providing access to research publications through the website, while 3 reported that their website did not.

2 US respondents reported that they published grant information on the website. 1 reported that they did not.

4 out of 5 respondents reported that they felt it was 'very' important to keep their institute website up to date.

1 US respondent reported that they had reservations about posting information on their website. The other four respondents reported that they did not have any reservations about posting information on the website.

Finally 4 US respondents reported that they felt their website was a good representation of the research conducted in their institute, while 1 reported that the website was a 'somewhat' good representation.

Under additional comments, one US respondent replied: "#16 donors and potential donors are important audiences for our website, as well as members of our Board of Trustees."

Ireland

4 communications personnel responded from Irish institutes.

Of them, all 4 reported to feel that their institute's website was 'very' important to external communication. 3 out of 4 ranked the website as the most important means of external communication, while one ranked press releases as the most important. In the comments for this question, one Irish communications personnel replied the following, "press releases probably first… followed by online material" while another replied, "web followed by press releases."

1 out of 4 Irish respondents reported that they spent 50% of their time maintaining their institute's website. The remaining three reported to spend 10%.

Three respondents reported that their institute had a member of staff dedicated to maintaining the website.

Three respondents reported that their institute involved research staff in creating content for the website. All three reported that their institute provided research staff with guidelines for web content creation. 3 of the 4 respondents reported that their institute gave research staff access to populate the website themselves. All three reported to edit that content prior to publication.

2 Irish respondents reported that their institute provided training for 'science writing for the public' while 2 reported the availability of training in 'use of the content management system'.

When asked if their institute allowed research staff to maintain a separate website, 1 Irish respondent reported that they did, while 2 reported it did not. Both positive repliers reported that they did not edit the content of these external sites.

In response to the question of the purpose an institute website should serve, Irish respondents reported the following; to provide contact details (3); to provide information on education and job openings (1); to provide news and upcoming event information (4); to provide current information on research (4); to provide detailed information on research (to include reports) (2).

All 4 of the Irish respondents reported that their institute targeted information to different audiences. Audiences reported as targeted included; other scientists (4); industrial partners (3); the media (4); the general public (4); postgraduate students (3); undergraduate students (3); secondary school students (3); primary school students (3); patients (0).

When asked how frequently they updated information on the website, 3 Irish respondents reported 'daily', while 1 reported 'weekly.'

3 Irish respondents reported that their website supported information with reference or sources while 1 reported their website did not. Of the three that reported 'yes', 1 reported that an 'abstract of research paper' was provided, another reported 'research images' were provided, while 2 reported that a 'list of research paper sources' was provided. 2 respondents reported to providing access to research publications through the website, while 2 reported that their website did not.

3 Irish respondents reported that they published grant information on the website. 1 reported that they did not.

All 4 respondents reported that they felt it was 'very' important to keep their institute website up to date.

1 Irish respondent reported that they had reservations about posting information on their website. They commented the following: "Given that nature of the industry-academic collaboration, there is Intellectual property sensitivity around some emerging research areas." The other three respondents reported that they did not have any reservations about posting information on the website.

Finally 3 Irish respondents reported that they felt their website was a good representation of the research conducted in their institute, while 1 reported that the website was a 'somewhat' good representation. Asked to comment, one Irish respondent replied: "the website was recently updated to reflect the dynamic nature of research within the Institute. There is not a full-time dedicated resource to the site, in an ideal funding scenario this would be the case! The site updates lie within the E & O team and updates happen on a bi-weekly basis. We believe the website acts as an opportunity for many of our stakeholders to find out more about us, but also as a method to get in touch with us. We don't publish long detailed information on the site, rather smaller." Another replied: "our website is sadly out of date, so we are currently recruiting for a communications officer to take on this responsibility for us. Once hired, the first priority for this person will be to totally revamp our website."

Continental Europe

2 communications personnel responded from Continental European institutes.

Of them, both reported to feel that their institute's website was 'very' important to external communication. Both respondents reported 'other' and commented: "Web" and "Most important: web."

Neither Continental-European respondent reported the amount of their time maintaining their institute's website.

Both respondents reported that their institute did not have a member of staff dedicated to maintaining the website. One respondent reported that their institute involved research staff in creating content for the website and that their institute provided research staff with guidelines for web content creation. Neither Continental-European respondent reported that their institute gave research staff access to populate the website themselves.

No form of training was reported as available to assist in populating the website.

When asked if their institute allowed research staff to maintain a separate website, one Continental-European respondent reported that their institute did, they did not however edit the content of these external sites.

In response to the question of the purpose an institute website should serve, Continental-European respondents reported the following; to provide contact details (0); to provide information on education and job openings (0); to provide news and upcoming event information (0); to provide current information on research (2); to provide detailed information on research (to include reports) (0).

One of the Continental-European respondents reported that their institute targeted information to different audiences. Audiences reported as targeted included; other scientists (2); industrial partners (1); the media (1); the general public (1); postgraduate students (0); undergraduate students (0); secondary school students (0); primary school students (0); patients (0).

1 Continental-European respondent reported that they updated information on the website daily.

Neither Continental-European respondent replied to the question of whether or not their institute supported information on research projects with reference or sources. When asked what type of sources they provide however, one respondent commented: "research images and media articles relating to research if available."

One Continental-European respondent reported that their institute did not publish grant information on the website.

1 Continental-European respondent reported that they felt it was 'very' important to keep the institute website up to date.

Both respondents reported no reservations about posting information on their website.

Finally both Continental-European respondents reported that they felt the website was a good representation of the research conducted in the institute.

Canada

2 communications personnel responded from Canadian institutes.

Of them, both reported to feel that their institute's website was 'very' important to external communication. One respondent ranked the website as the most important means of external communication, while the other reported 'other' and commented: "All important."

Both Canadian respondents reported that they spent 10% of their time maintaining their institute's website.

Neither respondent reported that their institute had a member of staff dedicated to maintaining the website, nor that they involved research staff in creating content for the website, nor gave research staff access to populate the website themselves.

No form of training was reported as available to assist in populating the website.

When asked if their institute allowed research staff to maintain a separate website, both Canadian respondents reported that they did. None of these reported that they edited the content of these external sites.

In response to the question of the purpose an institute website should serve, Canadian respondents reported the following; to provide contact details (2); to provide information on education and job openings (1); to provide news and upcoming event information (0); to provide current information on research (2); to provide detailed information on research (to include reports) (0).

One of the Canadian respondents reported that their institute targeted information to different audiences. Audiences reported as targeted included; other scientists (1); industrial partners (0); the media (1); the general public (1); postgraduate students (0); undergraduate students (0); secondary school students (0); primary school students (0); patients (0).

1 Canadian respondent reported that they published grant information on the website, while 1 reported that they did not.

1 Canadian respondent reported that they felt it was 'very' important to keep the institute website up to date.

1 Canadian respondent reported that they had reservations about posting information on their website.

Finally both Canadian respondents reported that they felt their website was a 'somewhat' good representation of the research conducted in the institute.

Under additional comments, one Canadian respondent replied: "While we know how important our website is, staff resources prevent us keeping it as up to date as we would like. We know our website could be improved."

UK

6 communications personnel responded from UK institutes.

Of them, all 6 reported to feel that their institute's website was 'very' important to external communication. 5 out of 6 ranked the website as the most important means of external communication, while one ranked online newsletters. In the comments for this question, one UK communications personnel replied with the following rank order, "1. Our website 2. Press releases 3. Emailed newsletters."

4 out of 6 UK respondents reported that they spent 10% of their time maintaining their institute's website. A further two reported to spend 25%.

Three respondents reported that their institute had a member of staff dedicated to maintaining the website.

Only 2 reported that their institute involved research staff in creating content for the website, while a further 4 reported that they did not. None of the 6 respondents reported that their institute gave research staff access to populate the website themselves.

4 UK respondents reported that their institute provided training for 'use of the content management system.' No other form of training was reported as available.

When asked if their institute allowed research staff to maintain a separate website, 5 UK respondents reported that they did. All five reported that they did not edit the content of these external sites.

In response to the question of the purpose an institute website should serve, UK respondents reported the following; to provide contact details (6); to provide information on education and job openings (4); to provide news and upcoming event information (5); to provide current information on research (5); to provide detailed information on research (to include reports) (0).

4 of the UK respondents reported that their institute targeted information to different audiences. Audiences reported as targeted included; other scientists (6); industrial partners (1); the media (4); the general public (6); postgraduate students (5); undergraduate students (1); secondary school students (0); primary school students (0); patients (1).

When asked how frequently they updated information on the website, 1 UK respondent reported 'daily'; 1 reported 'weekly'; 3 reported 'a few times per month'; while 1 reported 'a few times per year'.

2 UK respondents reported that their website supported information with reference or sources while 4 reported their website did not. Of the two that reported 'yes', 1 reported that a 'link to research paper in PubMed or similar' was provided. The other reported that a 'list of research paper sources' was provided. 1 respondent reported to providing access to research publications through the website, while 4 reported that their website did not.

5 UK respondents reported that they published grant information on the website. 1 reported that they did not.

All 6 respondents reported that they felt it was 'very' important to keep their institute website up to date.

4 UK respondents reported that they had reservations about posting information on their website. Of those 4, two commented the following: "animal research" and "it depends on the nature of the information."

Finally 4 UK respondents reported that they felt their website was a good representation of the research conducted in their institute, while 2 reported that the website was a 'somewhat' good representation. Asked to comment, one UK respondents replied: "We are beginning the process to redesign our research website."

Observations

While all respondents reported their institute website as 'very' important to external communication, differences emerge in approaches to Web communication when the results are analysed by country. The US and Ireland report more time spent maintaining the website than the other three countries, and target content to more audiences. The US and Ireland both involve research staff in content creation and allow research staff to play a more active role in posting information on the website.

US and Irish institutes are more likely to have a member of staff dedicated to maintaining the website.

Web training is more commonly available in the UK, Ireland and the US than it is in Canada and Continental Europe. While most countries' respondents report that they feel the website's purpose is to provide information on current research, only the US and Ireland reported providing detailed information on research (to include reports).

On a whole, these findings validate the results of the content analysis.

5: Discussion

5.1: Introduction

This study has shown, through the use of two methods to examine the websites of 68 biomedical science research institutes, the extent to which biomedical research institutes use the web as a means of communicating with public audiences. It has yielded both positive and negative examples of how the Web can be used to communicate with public audiences. Results have shown that a large number of the websites consider the public in creating content on their website, and present scientific information in such a way that it can be understood clearly from the perspective of a lay audience. It has also shown however that a large number of websites do not consider the public at all in creating content for the Web, populating their websites with dense, highly scientific language on research findings, or no research findings at all, instead focusing content on information about the institution rather than its research.

Like Lederbogen and Trebbe (2003), Trench and Delaney (2004), Massoli (2007) and Jaskowska (2008) before me, this study has shown that science research institutes, on a whole, are using the Web to communicate with fellow scientists more so than public audiences. Clear evidence has been found that these websites do more to promote the institution than to provide timely research reports presented in easy to understand language. Only a very select few sites make use of Web capabilities for facilitating dialogic or trust-building communication. Though excellent examples which contrast these trends have been identified, they are few.

Through the preceding literature review, it has been shown that biomedical research institutes can communicate information effectively by following a few clear guidelines. These include; targeting content at particular segments of their audience; providing in-depth yet accessible information; endeavouring to take an open approach to communication in order to build trust which does not attempt to shield the public from uncertainty; and blending different approaches to, or models of, communication. Though many sites meet one or two of these criteria, only a very select few websites meet them all.

Research has shown that biomedical research institutes in the United States surpass the other countries in their efforts to communicate with public audiences via the Web. Of the five highest scoring websites, four were located in the United States. On a whole however, the public communication of biomedical research does not appear to be the primary aim of online communication and the deficit model is still widely used with very little opportunity provided for user discussion or interaction.

5.2: Review of Results

In the literature review, a number of Web attributes were discussed, the presence of which were deemed necessary to the creation of a website that would yield a positive user experience. These included website credibility; usability features; interactivity; content; design 'look and feel'; and accessibility.

Results of the content analysis show that website credibility is an attribute given considerable attention by biomedical research institutes. Identification of the institute publishing the site is clear in 97% of websites. Design methods have also been clearly used in 94% of websites to clearly and consistently remind the user of the publisher responsible for the content.

Usability has also been closely considered with consistent navigation used in 94% of websites and standard usability tools widely used. Enhanced usability features such as sitemaps and breadcrumbs however are largely underused by the sample.

Interactivity however is grossly under considered by the websites. It is the potential for interactivity, as Stout et al. (2001, pg. 721) suggest, which makes the Web a "dynamic medium for influencing learning, attitude change and behaviour." This study found very few examples of websites which harness advances in Web technology to increase the possibility for users' and a site to collectively construct meaning.

The content presented on the sample websites meets few of Williams et al.'s (2002) criteria of being current, evidence based, backed by sources, and attributed to its author. Only 50% of homepages contain information that is less than one month old; 34% of content is backed by reference or sources; and 35% of content has a named author. Just half of the sites, allow for in-depth access to information, or as Trench (2008a) observed, "facilitate[e] public access to previously private spaces."

Website design is largely well considered with 91% of sites following a consistent design scheme. The vast majority of websites are presented in attractive formats making effective, and at times, innovative use of colour. Though not all sites make use of graphics, those that use images achieve a strong impact.

Finally, accessibility is well considered with the majority of websites ensuring ease of use to the widest range of potential users.

5.3: Identifying Models of Communication

Wynne (2006) and Trench's (2008b) suggestion that a significant shift from the deficit model to the dialogue model has not taken place is evidenced in the websites. Examples of the deficit model approach to communication can be seen widely in the sample. The predominant form of communication used by the institutes in this sample is one way, top down. Trench's claim that "the deficit model survives as the effective underpinning of much science communication" is proven by the results of this content analysis. Though Wynne (1989) referred to the deficit model as an inadequate model of communication because it left scientists having to correct the knowledge deficit of the scientifically illiterate public, the deficit model can in fact be used effectively. A problem arises with the realisation that many websites are not even making use of this approach as they are providing so little actual scientific information that it doesn't even qualify as meeting the deficit model.

Gregory and Miller (1998) suggest that a 'contextual approach' to science communication, which calls for scientific information to be given to the public in ways that relate to their specific interests and concerns. Evidence of this approach can be seen in a number of websites which present scientific research information by the illness, disease or health concern which it impacts rather than by the science discipline in which it falls. By doing so, information is presented to the public in a way that is instantly recognisable as relevant to them and which they can understand.

It is difficult to find evidence on the websites of biomedical science research institutes in any of the five regions of the dialogical approach to science communication that emerged in response to the backlash against the deficit model. Valenti and Wilkins (1995) suggest that this approach to science communication is a useful tool in building relationships between the scientific community and public audiences in order to establish trust, a key determinant of the public's attitude toward science. Developments in Web technology in recent years make it the ideal platform for enabling interactive communication between users on the Web.

Shapin's (1992) 'warts and all' approach to science communication is not in evidence among these websites. Science information is presented in positive language with emphasis on progress, furthering knowledge, improved treatments, and new expertise. The word 'challenge' is the most suggestive one used on the homepages of the websites, the only indication that the research is demanding, difficult, at times inconclusive or uncertain. What is in evidence however is a response to what he notes as the public's desire to understand not just science, but the role of scientists and the way in which science is created. Information about the scientists themselves is commonly found on the websites, with profile articles, interviews and Q&A's sharing information about the work and life of the scientist.

The sole indication that upstream engagement is taking place is in the presentation of research as 'new' on the institute websites. This however does not meet with Wilsdon and Willis' (2004) argument in favour of upstream engagement which calls for enabling effective engagement at a stage when it can inform key decisions. While some institutes are sharing information on new research with online audiences, none are engaging those audiences in online debates over decisions. The public audiences are in no way provided with an opportunity to shape nor inform decisions.

5.4: A Lack of Interaction

Recognition of the public as a diverse and varied group can be seen in those sites which divide the information they communicate by audience type. Einsiedel's 'active public' however is largely ignored, with little opportunity provided for the public to communicate back. Public audiences rather, are viewed as passive.

From its very inception, the Web was intended by Berners-Lee to be a collaborative space that enabled interaction. Development of the Web from 'read only' to 'read-write' has not been efficiently adopted by the science community. Opportunities for enhanced online participation are only provided in a select number of websites.

Use of the Web has transformed in recent decades as users begin to take on an active role in the creation of Web content. This emerging online trend is not however mirrored on the websites of biomedical research institutes. It is only in very rare cases that users are given an opportunity to contribute to content.

5.5: Methods of Best Practice

One of the aims of this study was to establish a set of guidelines which could be used to inform best practice. Effectively communicating science to the public is a complicated task to which a set of standards is difficult to apply. From this study however, examples emerge which could be used to guide science communication efforts on the Web. Biomedical research institutes which wish to use their websites as a means of communicating with public audiences can;

1. Communicate information effectively by forming a more complex understanding of 'the public'- recognising that the public is a complex and varied group; has existing knowledge about science which is formed and shaped by its local knowledge; and is active- a well

developed website should give the public a role to play by harnessing Web technology that allows for interactivity and enables the user to drive or create content.

2. Accepting that the public has a low level of scientific literacy but are capable of understanding complex ideas and therefore providing in-depth yet accessible information. By targeting content to different audiences, websites can deliver information that is geared both toward scientists, using colloquial language that does not simplify content, while also providing information for public audiences, be they adults or young people which uses appropriate language and explains the science in clear, understandable terms.

3. Endeavouring to take an open approach to communication, in order to build trust which does not attempt to shield the public from uncertainty. Research news and information presented on institute which only report on success and progress gives the public a false impression of scientific research process. Open communication means reporting on research success along with research failures which can be presented as learning blocks in the process of scientific discovery. Being open and forthright about the uncertainty of science also allows public audiences to gain a greater understanding of, and appreciation for, science research.

4. Blending different approaches to, or models of, communication according to the particular audience, issues, or context through a range of Web technologies that allows for interactivity and the creation of user driven content. The deficit model approach of providing information in a one-way form of communication can be an effective means of presenting explanations of ongoing research, its background, potential impacts and aims. A great deal of Web content can be presented effectively using this model. A well considered website will blend this method with dialogic models which encourages members of public audiences to communicate back, by asking questions, providing comments, or suggesting topics for discussion.

Furthering the effective design of a science website can be achieved by considering the findings of Triese et al. (2003, pg. 316) which shows that producers of science websites must bear two distinct groups in mind when designing and populating a website. Their work has shown that a measure of the credibility of science websites by those with a greater understanding of science will be based upon an "evaluation of the quality of arguments contained in the message itself" while a less informed user will "lack the ability to process a message [and will therefore] form opinions about the message based on factors other than the arguments contained therein." By focusing on the creation of high quality content which provides accurate, timely, honest and in-depth information on science research, the first group will be catered for. In order to meet the needs of the less informed public audiences, a website design which enables ease of use, is attractive, well-organised and contains writing of high quality, is required. In designing a website to meet both criteria, one can help to ensure that users perceive the credibility of the source and are able to differentiate a quality website from the many competitors offering information of lower quality or veracity.

5.6: Conclusions

Given the differing results found from country to country, the results of this study may reflect differences in science culture beyond the scope of this study. One could however seek explanations in the following areas. The US and the UK, in earning the highest scores overall, illustrate the impact of longstanding support for science communication in both countries. The US, with the establishment of the AAAS in 1848 saw the formation of a national culture which recognised the importance of generating public interest in and support for science. Through a range of public interest programmes, the AAAS has long acted as a bridge between the scientific community and the general public to advance public understanding of science and technology. The work of Dewy in the early 1930s also helped to create an environment in the US which places emphasis on the importance of educating young people in order to instil in them a 'scientific attitude' which would help them to approach life in a rational and logical way. This culture of science promotion and public communication has no doubt had an impact on the policies and practices of research institutes in the US.

The Public Understanding of Science movement in the UK has also had a significant impact on science culture. With publication of the Bodmer report in 1985, the scientific community in the UK was called upon to learn to communicate with the public, with the Royal Society making the improvement of the public understanding of science one of its principal activities. The formation of COPUS, and subsequent emergence of a call for public engagement, has seen public communication of science activities, and funding, increase dramatically over the past three decades. Like the influence of the AAAS and its activities in the US, the actions of the Royal Society have no doubt had an influence on the practices of science research institutes in the UK. As this study has shown, however, further progress is required in both the US and the UK, along with Ireland, Canada and Continental Europe if the public communication of science is to become a principal aim of biomedical science research institutes' communication policies.

The Web presents biomedical science research institutes with the opportunity to make information constantly available to a vast audience for relatively little cost. As a broadcast tool it cannot be beaten for its efficiency. This study has shown however that the Web is being underused by this segment of the scientific community, with vast tools at its disposal underused if not entirely ignored. The opportunity to share in-depth information on scientific information and then enable dialogue and discussion between the scientific community and public audiences is being missed. The public are not being ignored; they are just not being afforded an opportunity to be heard.

6: Conclusion

With its inherent properties of accessibility and interactivity, the Web has the potential to be one of the most comprehensive tools currently available to the field of biomedical science for the dissemination of information on research and findings to public audiences. The principal aim of this study was to ascertain the extent to which this tool was being used.

Given that the number of websites presenting science and health news and background information has risen sharply since 2001, and the number of people consulting these websites has also risen, now more than ever, the Web is a tool for communication that can be harnessed by any institute wishing to communicate with public audiences. The websites of biomedical science research institutes have the potential to serve as a primary source of this scientific information, providing in-depth, accurate and trustworthy content on the latest scientific developments. To date science is not making effective use of the communication medium it helped construct. Peterson (2001, pg. 250) in noting gaps in the Web's coverage of science highlighted a lack of "timely reports devoted to conveying and explaining scientific research or medical advances to the public." As a primary source of this information, the websites of biomedical science research institutes could be filling this gap.

Both science and society stand to benefit from a strong foundation of civic scientific literacy and the scientific community, as primary sources, have an essential role to play in providing a foundation of knowledge. This study has shown however, that institutes are not currently fulfilling this role. The scientific community have the ability to share information that could see the public develop a foundation of scientific literacy, leading to an increased interest in and appreciation of science. This study has shown that examples of effective online public engagement are few, but are present. It is the institute's recognition of the role of public audiences in the communication process that is most lacking.

On a whole, use of the Web has changed the way that people use the Web from an information source to a platform for interactive communication. This has not however, according to the findings of this study, manifested itself in the websites of biomedical science research institutes. Both J.D. Miller (2001) and Horrigan (2006) identify science Web users as predominantly well-educated males, a small fraction of potential online audiences. Efforts could be made to broaden this audience to include a wider segment of the population.

Having established interactive platforms for communicating information to diverse public audiences at their disposal, research institutes have an opportunity to develop relationships of trust with those audiences to ensure effective communication. In order for trust in science to be maintained, open and early information sharing must be carried out (Wynne, 1989; Shapin, 1992; Doble, 1995). This, along with recognition of and respect for the public's socially and politically constructed knowledge and individually perspective will combine to form a healthy relationship between science and society (Wynne, 1995; Irwin, 2007). This can best be achieved through approaches to communication which blend dissemination, dialogue, and engagement to form a model unique to each context (Trench, 2008; Irwin, 2008.) This study has shown that the scientific community have work to do if they wish to meet this goal through institutional websites.

Aforementioned studies have shown that people who seek out news and information about science on the Web are more likely to believe that science has a positive impact on society and that science plays a positive role in improving society, the quality of human lives and the nation's well-being. With an opportunity to provide 'vicarious contact' with the science community, the Web can have a positive influence on young people's perception of science by enabling interaction with real-life role models. The Web doesn't simply have the ability to inform public audiences about science, it stands to impact the way that public audiences feel about science.

Excellent examples of ways in which biomedical science research institutes can communicate with a range of public audiences have been identified through this study. Models of best practice exist and can be used by institutes to modify and improve use of their website in order to make better use of the Web's capacity for providing an interactive communication platform which can enable online audiences to take an active role in science communication. On a whole, it is clear that the majority of biomedical science research institutes use the Web as a means of communicating general information about their institute to some segments of the online audience. With all that it stands to offer institutes, the Web should be designated a principal tool for external communication. Given its inherent capacity to reach a broad and diverse public, the website of a research institute could be tailored toward a range of public audiences, delivering content prepared for each audience, openly communicating science information as it emerges, in a way that allows those members of the public to communicate back.

Appendices

Appendix A

List of websites to be included in evaluation

UK

1. The Sanger Institute- http://www.sanger.ac.uk/
2. Beatson Oncology Centre- http://www.beatson.org.uk/
3. Wellcome Trust Centre for Cell Biology, University of Edinburgh- http://www.wcb.ed.ac.uk/
4. The Wolfson Institute for Biomedical Research - http://www.ucl.ac.uk/wibr/
5. Biomedical Research Centre, University of Dundee- http://www.dundee.ac.uk/biomedres/welcome.htm
6. Biomedical Research Centre, Sheffield Hallam University- http://www.shu.ac.uk/research/bmrc/
7. The Krebs Institute, University of Sheffield- http://www.krebs.group.shef.ac.uk/index.html
8. Biomedical Science Research Institute, University of Salford- http://www.ibms.org/index.cfm?method=site.home
9. Edinburgh Cancer Research Centre- http://www.ecrc.ed.ac.uk/
10. Cambridge Neuroscience- http://www.neuroscience.cam.ac.uk/
11. Cancer Research UK Cambridge Research Institute- http://www.cambridgecancer.org.uk/
12. Institute of Biomedical Engineering, Imperial College of London- http://www3.imperial.ac.uk/biomedeng
13. Weatherall Institute of Molecular Medicine, University of Oxford- http://www.imm.ox.ac.uk/index.htm
14. Oxford Biomedical Research Centre - http://www.oxfordradcliffe.nhs.uk/obrc/home.aspx
15. Bimolecular and Biomedical Research Centre- http://www.northumbria.ac.uk/sd/academic/sas/rande/research/bbrc/
16. Institute of Cancer Research- http://www.icr.ac.uk/
17. UCL Cancer Institute- http://www.ucl.ac.uk/cancer/
18. Bloomsbury Centre for Bioinformatics- http://bioinf.cs.ucl.ac.uk/bcb/
19. Paterson Institute for Cancer Research- http://www.paterson.man.ac.uk/
20. Gray Cancer Institute- http://www.gci.ac.uk/
21. Centre for Biomolecular Sciences- http://www.nottingham.ac.uk/cbs/
22. MRC Centre for Developmental Neurobiology, King's College London- http://www.kcl.ac.uk/depsta/biomedical/mrc/

Ireland

23. The Conway Institute- http://www.ucd.ie/conway/
24. Regenerative Medicine Institute (REMEDI)- http://www.remedi.ie
25. Centre for Bioanalytical Science (CBAS)- http://www.cbas.ie/
26. Biomedical Diagnostics Institute (BDI)- http://www.bdi.ie/
27. Alimentary Pharmabiotic Centre- http://www.ucc.ie/research/apc/content/
28. Tyndall National Institute- http://www.tyndall.ie/
29. National Institute for Bioprocessing Research and Training, Trinity College Dublin- http://www.nibrt.ie/
30. Royal College of Surgeons Research Institute- http://www.rcsi.ie/index.jsp?1nID=93&pID=96&nID=127

US

31. Whitehead Institute for Biomedical Research- http://www.wi.mit.edu/
32. Institute for Systems Biology- http://www.systemsbiology.org/
33. Sloan Kettering Institute- http://www.mskcc.org/mskcc/html/5804.cfm
34. Cold Spring Harbour Laboratory- http://www.cshl.edu/
35. The Broad Institute- http://www.broad.mit.edu/
36. The CBR Institute- http://cbr.med.harvard.edu/
37. The Scripps Research Institute- http://www.scripps.edu/e_index.html
38. QB3- http://www.qb3.org/
39. Mayo Clinic- http://www.mayo.edu/
40. McGowan Institute for Regenerative Medicine- http://www.mirm.pitt.edu/
41. National Institute of Biomedical Imaging and Bioengineering- http://www.nibib.nih.gov/
42. Howard Hughes Medical Institute- http://www.hhmi.org/
43. Burnham Institute for Medical Research- http://www.burnham.org/
44. Weill Institute for Cell and Molecular Biology, Cornell University - http://www.icmb.cornell.edu/
45. Stanford Cancer Centre- http://cancer.stanford.edu/
46. Jonsson Comprehensive Cancer Centre, UCLA- http://www.cancer.ucla.edu/
47. Institute for Bioengineering and Bioscience, Georgia Tech- http://www.ibb.gatech.edu/
48. Sackler Institute of Graduate Biomedical Studies, NYU- http://www.med.nyu.edu/sackler/
49. Institute for Basic Biomedical Sciences, Johns Hopkins University- http://www.hopkinsmedicine.org/ibbs/
50. Yale Cancer Centre- http://yalecancercenter.org//index.html
51. Duke Human Vaccine Institute- http://humanvaccine.duke.edu/
52. Beckman Institute, Cal Tech- http://www.its.caltech.edu/~bi/
53. Princeton Neuroscience Institute- http://neuroscience.princeton.edu/cgi-bin/neuro/site/home.pl
54. Chicago Biomedical Consortium- http://chicagobiomedicalconsortium.org/

Canada

55. Genome Quebec Innovation Centre- http://www.genomequebecplatforms.com
56. Institute of Biomaterials and Biomedical Engineering- http://www.ibbme.utoronto.ca/site4.aspx
57. Biomedical Research Centre, University of British Columbia- http://www.brc.ubc.ca/brc/
58. Vancouver Coastal Health Research Institute (VCHRI)- http://www.vchri.ca/s/Home.asp
59. McGill Cancer Centre- http://cancercentre.mcgill.ca/research/
60. Centre for Evaluation of Medicines, McMaster University- http://www.thecem.net/index.php
61. Cancer Research Institute, Queen’s University- http://qcri.queensu.ca/Welcome.html
62. Dalhousie Infectious Disease Research Alliance- http://didra.medicine.dal.ca/
63. l’Institut de génie biomédical, l'Université de Montréal- http://www.igb.umontreal.ca/

Continental Europe

64. Georg-Speyer-Haus- http://www.georg-speyer-haus.de/
65. Max Planck Society- http://www.mpg.de/english/portal/index.html
66. Pasteur Institute- http://www.pasteur.fr/english.html
67. Institute of Molecular Biology and Pathology- http://www.ibpm.cnr.it/Inglese/institute.html
68. INSERM- http://www.inserm.fr/fr/

Appendix B

Coding Framework with Results

Section 1 Identity (contextual information)

1.1 What kind of organisation does the website represent?

1.2 What is the principal area of research?

	Variable	% Yes	% No
2	Attribution and Transparency		
2.1	Does the site have an "About us" section?	96	4
2.2	Is the identity of the publishers clearly stated?	97	3
2.3	Does the site contain a statement on the publisher's expertise in the content area?	96	4
2.4	Does the website contain a statement on the purpose of its publisher?	96	4
2.5	Does the website contain a statement on its own specific purpose (mention in Disclaimer not sufficient)?	9	91
2.6	Are the key funding agencies of the research centre listed?	50	50
2.7	Is the url indicative of the research centre? name is an acronym. Does not contain any reference to science, contains unusual characters (such as ~) name is an acronym (or is undescriptive), does not contain any reference to science, contains no unusual characters name is an acronym but contains science reference, contains no unusual characters name is not an acronym, contains reference to science, or is full name of institute, contains no unusual characters	 4 28 31 35	
3	Content and Currency		
3.1	Does the website target specific audience(s)?	90	10
3.2	If yes, who is that audience? (add one point for each targeted group for a total of 8)	Avg. 4	
3.3	Does the majority of content appear with date of posting?	59	41
3.4	Does the majority of content appear with an authors' name?	35	65
3.5 3.6 3.7 3.8	Is last update on home page older than one year? Is last update on home page older than 6 months - one year? Is last update on home page older than 1 month - 6 months? Is last update on home page less than 1 month old?	9 1 25 50	
3.9	What kind of content is most immediately available (homepage)? Information on the institution, staff, contacts Information on courses News and recent events Current research projects Recent research findings (to include reports)	 15 4 46 7 25	
3.10	Is the scientific content supported by reference, sources?	34	66
3.11	Is website content copyright free?	21	79
3.12	Does the site contain a listing of research publications?	96	4
3.13	Is there a publication archive?	69	31
3.14	If yes, how many years does the archive go back? (add one per year to a total of 4)	Avg. 3	
3.15	Are research publications available to view on the site?	57	43
3.16	Are research publications available to download from the site?	60	40
3.17	Are the number of PhDs graduated each year listed on the site?	7	93
3.18	Are research grants received listed on the site?	31	69
3.19	Is the homepage content free from spelling and grammar mistakes?	93	7
3.20	Is text on the principal pages free from spelling and grammar mistakes? (3 pages to be analysed per site)	87	13
3.21	Does the website refer to other sources for information and views (hyperlinked from content)?	38	62
3.22	If yes, are the sites international? Within the home country Within the home continent International	 21 10 6	
3.23	If the answer to question 3.11 is yes, what kind of sites?		
3.24	Does the website have a Links section?	41	59
3.25	If yes, what kind of sites are included in the Links section?		

3.26	Does the website explain scientific terms?	54	46
3.27	If yes, where does it do so? In a separate glossary of scientific terms Beside the text Within the text	 0 1 53	
3.28	Does the website contain a News, recent developments or media section (containing press releases)?	76	24
3.29 3.30 3.31 3.32	If yes, is the most recent item older than one year? Is last update on home page older than 6 months - one year? Is last update on home page older than 1 month - 6 months? Is last update on home page less than 1 month old?	7 1 21 41	
3.33	Are older items archived or removed from the site?	62	38
3.34	Is there an events listing?	87	13
3.35	If yes, what type of events are listed? events for staff, students events open to the public events aimed at the public	 43 7 31	
3.36	If yes, what audiences do the events target? (add one point for each targeted group for a total of 4)	Avg. 1.5	
3.37	Does the website contain a listing of press coverage in the media?	22	78
3.38	Is there a "live newsfeeds" section? (from media, publishers, etc.)	3	97
3.39	If yes, where is material predominantly from? Within the home country Within the home continent International	 0 0 2	
3.40	Can users subscribe to a RSS feed?	31	69
3.41	Does the website contain researchers’ contact details?	93	7
3.42	If yes, what information is given: office phone, email, mobile phone? email office phone mobile number	 13 75 1	
4	Navigation and Interactivity		
4.1	Does the site have a sitemap?	35	65
4.2	Does the site have a search engine?	71	29
4.3	Does the site have drop-down menus for navigation?	68	32
4.4	Is there a link to the homepage on all other pages of the website?	91	9
4.5	Does the site make use of breadcrumbs to illustrate navigation paths?	34	66
4.6	Does the site make use of a main navigation bar that appears throughout?	91	9
4.7	Does the page title appear on the web browser's top window bar?	62	38
4.8	Is the website free from broken links?	88	12
4.9	Does the website have a mechanism to contact the publisher (e.g “Contact Us” section)?	91	9
4.10	Are contact details for the webmaster provided?	34	66
4.11	Does the site have a discussion board?	1	99
4.12	Does the site have a message board?	1	99
4.13	Does the site offer a subscription newsletter?	28	72
4.14	Does the site survey users for feedback?	9	91
4.15	Does the site contain any opinion polls?	0	
4.16	Does the website provide any results of evaluation of its effectiveness or impact?	0	
4.17	Does the website specify whether and how users' personal information and anonymity are protected, e.g., privacy statement?	50	50
4.18	Does the website specify who has access to information about its users?	50	50
5	Design		
5.1	Do the pages follow consistent layout, colour scheme and style?	91	9
5.2	Does use of colour enhance the site?	35	65
5.3	Does the site have a fluid layout?	85	15
5.4	Are the pages short- do not require scrolling?	50	50
5.5	Does the website use graphics, photos, animations, video and audio to aid in scientific illustration? (add 1 for each, total of 5)	Avg. 2	
5.6	Is the homepage easily recognisible as the homepage?	97	3
5.7	Does the homepage have links to all significant areas of the site?	93	7

5.8	Does the homepage include a 'tagline' that accurately and succinctly outlines the purpose of the site?	4	96
5.9	Can the homepage be viewed on one screen?	75	25
5.10	Is the corporate logo in a consistent place on all pages?	94	6
5.11	Are the most important items on each page located in the top/centre?	88	12
5.12	Does the site automatically adjust to monitor resolution settings?	97	3
5.13	Does the site support Firefox?	97	3
6	Accessibility		
6.1	Can the website be accessed without special and/or high level technology?	99	1
6.2	Does the site have a “text only” option?	6	94
6.3	Can the font size be adjusted?	7	93
6.4	Are the background colour and text easily read?	99	1
6.5	Are multimedia files presented in an accessible format?	56	44
6.6	Do graphic links have equivalent text links?	62	34
6.7	Does the website impair a user's ability to use their back button?	4	96
6.8	Is the navigation system constant throughout the site?	94	6

Appendix C

List of sites with overall score

	Institute and Url	Country	Overall Score
1.	Whitehead Institute for Biomedical Research- http://www.wi.mit.edu/	US	100
2.	Howard Hughes Medical Institute- http://www.hhmi.org/	US	98
3.	Max Planck Society- http://www.mpg.de/english/portal/index.html	C-Eu	96
4.	The Scripps Research Institute- http://www.scripps.edu/e_index.html	US	95
5.	Mayo Clinic- http://www.mayo.edu/	US	91
6.	The Conway Institute- http://www.ucd.ie/conway/	Ire	90
7.	The Broad Institute- http://www.broad.mit.edu/	US	88
8.	The Sanger Institute- http://www.sanger.ac.uk/	UK	88
9.	Institute for Systems Biology- http://www.systemsbiology.org/	US	87
10	Cold Spring Harbour Laboratory- http://www.cshl.edu/	US	87
11	National Institute of Biomedical Imaging and Bioengineering- http://www.nibib.nih.gov/	US	85
12	Institute of Cancer Research- http://www.icr.ac.uk/	UK	84
13	Burnham Institute for Medical Research- http://www.burnham.org/	US	83
14	Biomedical Diagnostics Institute (BDI)- http://www.bdi.ie/	Ire	82
15	Stanford Cancer Centre- http://cancer.stanford.edu/	US	82
16	Cambridge Neuroscience- http://www.neuroscience.cam.ac.uk/	UK	80
17	Jonsson Comprehensive Cancer Centre, UCLA- http://www.cancer.ucla.edu/	US	78
18	Institute for Basic Biomedical Sciences, Johns Hopkins University- http://www.hopkinsmedicine.org/ibbs/	US	78
19	Tyndall National Institute- http://www.tyndall.ie/	Ire	77
20	Genome Quebec Innovation Centre- http://www.genomequebecplatforms.com	CA	76
21	The Wolfson Institute for Biomedical Research - http://www.ucl.ac.uk/wibr/	UK	75
22	Cancer Research UK Cambridge Research Institute- http://www.cambridgecancer.org.uk/	UK	74
23	Regenerative Medicine Institute (REMEDI)- http://www.remedi.ie	Ire	74
24	QB3- http://www.qb3.org/	US	74
25	Sloan Kettering Institute- http://www.mskcc.org/mskcc/html/5804.cfm	US	73
26	The CBR Institute- http://cbr.med.harvard.edu/	US	73
27	Duke Human Vaccine Institute- http://humanvaccine.duke.edu/	US	72
28	Vancouver Coastal Health Research Institute (VCHRI)- http://www.vchri.ca/s/Home.asp	CA	72
29	McGowan Institute for Regenerative Medicine- http://www.mirm.pitt.edu/	US	71
30	Beatson Oncology Centre- http://www.beatson.org.uk/	UK	70
31	UCL Cancer Institute- http://www.ucl.ac.uk/cancer/	UK	70
32	Alimentary Pharmabiotic Centre- http://www.ucc.ie/research/apc/content/	Ire	70
33	Yale Cancer Centre- http://yalecancercenter.org//index.html	US	70
34	Sackler Institute of Graduate Biomedical Studies, NYU- http://www.med.nyu.edu/sackler/	US	67
35	Chicago Biomedical Consortium- http://chicagobiomedicalconsortium.org/	US	67
36	Institute for Bioengineering and Bioscience, Georgia Tech- http://www.ibb.gatech.edu/	US	66

37	Pasteur Institute- http://www.pasteur.fr/english.html	C-Eu	65
38	Georg-Speyer-Haus- http://www.georg-speyer-haus.de/	C-Eu	64
39	McGill Cancer Centre- http://cancercentre.mcgill.ca/research/	CA	63
40	MRC Centre for Developmental Neurobiology, King's College London- http://www.kcl.ac.uk/depsta/biomedical/mrc/	UK	62
41	Institute of Biomaterials and Biomedical Engineering- http://www.ibbme.utoronto.ca/site4.aspx	CA	62
42	Institute of Biomedical Engineering, Imperial College of London- http://www3.imperial.ac.uk/biomedeng	UK	61
43	Weill Institute for Cell and Molecular Biology, Cornell University - http://www.icmb.cornell.edu/	US	61
44	Paterson Institute for Cancer Research- http://www.paterson.man.ac.uk/	UK	60
45	Cancer Research Institute, Queen's University- http://qcri.queensu.ca/Welcome.html	CA	60
46	Princeton Neuroscience Institute- http://neuroscience.princeton.edu/cgi-bin/neuro/site/home.pl	US	59
47	Biomedical Research Centre, University of British Columbia- http://www.brc.ubc.ca/brc/	CA	59
48	Gray Cancer Institute- http://www.gci.ac.uk/	UK	58
49	National Institute for Bioprocessing Research and Training, Trinity College Dublin- http://www.nibrt.ie/	Ire	58
50	l'Institut de génie biomédical, l'Université de Montréal- http://www.igb.umontreal.ca/	CA	58
51	Biomedical Science Research Institute, University of Salford- http://www.ibms.org/index.cfm?method=site.home	UK	57
52	Royal College of Surgeons Research Institute- http://www.rcsi.ie/index.jsp?1nID=93&pID=96&nID=127	Ire	56
53	Centre for Bioanalytical Science (CBAS)- http://www.cbas.ie/	Ire	55
54	Centre for Evaluation of Medicines, McMaster University- http://www.thecem.net/index.php	CA	55
55	Wellcome Trust Centre for Cell Biology, University of Edinburgh- http://www.wcb.ed.ac.uk/	UK	50
56	Bloomsbury Centre for Bioinformatics- http://bioinf.cs.ucl.ac.uk/bcb/	UK	50
57	Biomedical Research Centre, Sheffield Hallam University- http://www.shu.ac.uk/research/bmrc/	UK	49
58	The Krebs Institute, University of Sheffield- http://www.krebs.group.shef.ac.uk/index.html	UK	49
59	Centre for Biomolecular Sciences- http://www.nottingham.ac.uk/cbs/	UK	49
60	Weatherall Institute of Molecular Medicine, University of Oxford- http://www.imm.ox.ac.uk/index.htm	UK	48
61	Biomedical Research Centre, University of Dundee- http://www.dundee.ac.uk/biomedres/welcome.htm	UK	46
62	Beckman Institute, Cal Tech- http://www.its.caltech.edu/~bi/	US	44
63	Edinburgh Cancer Research Centre- http://www.ecrc.ed.ac.uk/	UK	43
64	INSERM- http://www.inserm.fr/fr/	C-Eu	43
65	Dalhousie Infectious Disease Research Alliance- http://didra.medicine.dal.ca/	CA	42
66	Oxford Biomedical Research Centre - http://www.oxfordradcliffe.nhs.uk/obrc/home.aspx	UK	41
67	Bimolecular and Biomedical Research Centre- http://www.northumbria.ac.uk/sd/academic/sas/rande/research/bbrc/	UK	39
68	Institute of Molecular Biology and Pathology http://www.ibpm.cnr.it/Inglese/institute.html	C-Eu	-

Appendix D

Content Analysis Results by Country

Institute and Url	Country	Overall Score
Whitehead Institute for Biomedical Research- http://www.wi.mit.edu/	US	100
Howard Hughes Medical Institute- http://www.hhmi.org/	US	98
The Scripps Research Institute- http://www.scripps.edu/e_index.html	US	95
Mayo Clinic- http://www.mayo.edu/	US	91
The Broad Institute- http://www.broad.mit.edu/	US	88
Institute for Systems Biology- http://www.systemsbiology.org/	US	87
Cold Spring Harbour Laboratory- http://www.cshl.edu/	US	87
National Institute of Biomedical Imaging and Bioengineering- http://www.nibib.nih.gov/	US	85
Burnham Institute for Medical Research- http://www.burnham.org/	US	83
Stanford Cancer Centre- http://cancer.stanford.edu/	US	82
Jonsson Comprehensive Cancer Centre, UCLA- http://www.cancer.ucla.edu/	US	78
Institute for Basic Biomedical Sciences, Johns Hopkins University- http://www.hopkinsmedicine.org/ibbs/	US	78
QB3- http://www.qb3.org/	US	74
Sloan Kettering Institute- http://www.mskcc.org/mskcc/html/5804.cfm	US	73
The CBR Institute- http://cbr.med.harvard.edu/	US	73
Duke Human Vaccine Institute- http://humanvaccine.duke.edu/	US	72
McGowan Institute for Regenerative Medicine- http://www.mirm.pitt.edu/	US	71
Yale Cancer Centre- http://yalecancercenter.org//index.html	US	70
Sackler Institute of Graduate Biomedical Studies, NYU- http://www.med.nyu.edu/sackler/	US	67
Chicago Biomedical Consortium- http://chicagobiomedicalconsortium.org/	US	67
Institute for Bioengineering and Bioscience, Georgia Tech- http://www.ibb.gatech.edu/	US	66
Weill Institute for Cell and Molecular Biology, Cornell University - http://www.icmb.cornell.edu/	US	61
Princeton Neuroscience Institute- http://neuroscience.princeton.edu/cgi-bin/neuro/site/home.pl	US	59
Beckman Institute, Cal Tech- http://www.its.caltech.edu/~bi/	US	44
The Sanger Institute- http://www.sanger.ac.uk/	UK	85
Institute of Cancer Research- http://www.icr.ac.uk/	UK	84
Cambridge Neuroscience- http://www.neuroscience.cam.ac.uk/	UK	80
The Wolfson Institute for Biomedical Research - http://www.ucl.ac.uk/wibr/	UK	75
Cancer Research UK Cambridge Research Institute- http://www.cambridgecancer.org.uk/	UK	74
Beatson Oncology Centre- http://www.beatson.org.uk/	UK	70
UCL Cancer Institute- http://www.ucl.ac.uk/cancer/	UK	70
MRC Centre for Developmental Neurobiology, King's College London- http://www.kcl.ac.uk/depsta/biomedical/mrc/	UK	62
Institute of Biomedical Engineering, Imperial College of London- http://www3.imperial.ac.uk/biomedeng	UK	61
Paterson Institute for Cancer Research- http://www.paterson.man.ac.uk/	UK	60
Gray Cancer Institute- http://www.gci.ac.uk/	UK	58
Biomedical Science Research Institute, University of Salford-	UK	57

http://www.ibms.org/index.cfm?method=site.home		
Wellcome Trust Centre for Cell Biology, University of Edinburgh- http://www.wcb.ed.ac.uk/	UK	50
Bloomsbury Centre for Bioinformatics- http://bioinf.cs.ucl.ac.uk/bcb/	UK	50
Biomedical Research Centre, Sheffield Hallam University- http://www.shu.ac.uk/research/bmrc/	UK	49
The Krebs Institute, University of Sheffield- http://www.krebs.group.shef.ac.uk/index.html	UK	49
Centre for Biomolecular Sciences- http://www.nottingham.ac.uk/cbs/	UK	49
Weatherall Institute of Molecular Medicine, University of Oxford- http://www.imm.ox.ac.uk/index.htm	UK	48
Biomedical Research Centre, University of Dundee- http://www.dundee.ac.uk/biomedres/welcome.htm	UK	46
Edinburgh Cancer Research Centre- http://www.ecrc.ed.ac.uk/	UK	43
Oxford Biomedical Research Centre - http://www.oxfordradcliffe.nhs.uk/obrc/home.aspx	UK	41
Bimolecular and Biomedical Research Centre- http://www.northumbria.ac.uk/sd/academic/sas/rande/research/bbrc/	UK	39
The Conway Institute- http://www.ucd.ie/conway/	Ire	90
Biomedical Diagnostics Institute (BDI)- http://www.bdi.ie/	Ire	82
Tyndall National Institute- http://www.tyndall.ie/	Ire	77
Regenerative Medicine Institute (REMEDI)- http://www.remedi.ie	Ire	74
Alimentary Pharmabiotic Centre- http://www.ucc.ie/research/apc/content/	Ire	70
National Institute for Bioprocessing Research and Training, Trinity College Dublin- http://www.nibrt.ie/	Ire	58
Royal College of Surgeons Research Institute- http://www.rcsi.ie/index.jsp?1nID=93&pID=96&nID=127	Ire	56
Centre for Bioanalytical Science (CBAS)- http://www.cbas.ie/	Ire	55
Max Planck Society- http://www.mpg.de/english/portal/index.html	C-Eu	96
Pasteur Institute- http://www.pasteur.fr/english.html	C-Eu	65
Georg-Speyer-Haus- http://www.georg-speyer-haus.de/	C-Eu	64
INSERM- http://www.inserm.fr/fr/	C-Eu	43
Institute of Molecular Biology and Pathology http://www.ibpm.cnr.it/Inglese/institute.html	C-Eu	-
Genome Quebec Innovation Centre- http://www.genomequebecplatforms.com	CA	76
Vancouver Coastal Health Research Institute (VCHRI)- http://www.vchri.ca/s/Home.asp	CA	72
McGill Cancer Centre- http://cancercentre.mcgill.ca/research/	CA	63
Institute of Biomaterials and Biomedical Engineering- http://www.ibbme.utoronto.ca/site4.aspx	CA	62
Cancer Research Institute, Queen's University- http://qcri.queensu.ca/Welcome.html	CA	60
Biomedical Research Centre, University of British Columbia- http://www.brc.ubc.ca/brc/	CA	59
l'Institut de génie biomédical, l'Université de Montréal- http://www.igb.umontreal.ca/	CA	58
Centre for Evaluation of Medicines, McMaster University- http://www.thecem.net/index.php	CA	55
Dalhousie Infectious Disease Research Alliance- http://didra.medicine.dal.ca/	CA	42

Appendix E

Survey Questions and Results of Survey Questionnaire by Communications Officers

1. What kind of research organisation do you work for?

university department	1
university-based research institute	8
state research institute	2
independent research institute	5
research hospital	2
Other	1
Unanswered	1

If other, please specify:

school of medicine

2. What is your principal area of research?

biomedical science	10
biomedical engineering	2
Cancer	3
Neuroscience	0
Biology	0
regenerative medicine	1
molecular medicine	0

Genomics	0
Imaging	0
Bioinformatics	0
Other	2
Unanswered	3

If other, please specify:

systems biology
All of the above

3. How important is your institute's website to your external communication?

Very	19
Somewhat	0
not at all	0
Unanswered	2

4. Please rank the following means of external communication according to their importance to your institute:

Brochure	0
Website	13
press releases	3
public events	0
printed/online newsletters	1
annual report	0

outreach activities	0
Other	2
Unanswered	2

If other, please specify:

Press releases probably first...followed by online material
1. press releases 2. website 3. electronic newsletters 4. educational events for science writers/journalists
Website overall, but news releases for media, printed institutional news for partners and donors, etc. These also appear on the website.
Most important: web
All important
Web
1. our website 2. press releases 3. emailed newsletters
web followed by press releases

5. What percentage of your time is devoted to maintaining your institute's website?

10%	10
25%	3
50%	2
75%	0
100%	0
Unanswered	2

6. Do you have a member of staff dedicated to maintaining the website?

Yes	11
No	4
Unanswered	2

7. Does your research institute involve research staff in creating content for the website?

Yes	11
No	4
Unanswered	2

8. If yes, does your research institute provide research staff with guidelines for web content creation?

Yes	14
No	3
Unanswered	3

9. Does your research institute give research staff access to populate the website themselves?

Yes	8
No	10
Unanswered	2

10. If yes, do you edit the content that your research staff post on the institute website prior to publication?

Yes	6
No	7
Unanswered	8

11. Does your research institute provide training to assist you in populating the website in any of the following areas?

writing for the web	0
science writing for the public	3
use of the content management system	11
Other	0
Unanswered	3

12. Does your research institute allow research staff to maintain a separate webpage/website for their own research groups?

Yes	14
No	2
Unanswered	2

13. If yes, do you edit the content that researchers post on their separate webpage/website prior to publication?

Yes	0
No	15
Unanswered	6

14. What purpose do you feel an institute website should serve (you may select more than one option)?

to provide contact details, general institute information	13
to provide information on education and job openings	10

to provide news and upcoming event information	13
to provide information on current research	16
to provide detailed information on research (to include reports)	5

15. Does your institute website target information to different audiences?

Yes	15
No	0
Unanswered	2

16. If so, what audiences are catered for?

other scientists	16
industrial partners	8
the media	15
the general public	17
postgraduate students	13
undergraduate students	9
secondary school students	6
primary school students	4
patients	4

17. How frequently do you update information on the website?

Daily	8
Weekly	3

a few times per month	3
Monthly	0
a few times per year	1
Annually	0
Unanswered	5

18. Do you support information on research projects with reference or sources?

Yes	10
No	5
Unanswered	6

19. If yes, what types of sources do you provide? (you may select more than one)

abstract of research paper	1
complete research paper	0
link to research paper in PubMed or similar	1
research images	1
list of research paper sources	5
Other	2
Unanswered	8

If other, please specify:

Summaries of research written specifically for our website, with sources
All of the above, depending on the article

Research images and media articles relating to research if available

20. Do you provide access to research publications through the website?

Yes	5
No	10
Unanswered	6

21. Do you publicise grant information on the website?

Yes	11
No	4
Unanswered	5

22. How important do you feel it is to keep your institute website up-to-date?

Very	15
Somewhat	0
not at all	0
Unanswered	2

23. Do you have any reservations about posting information on your institute website?

Yes	6
No	12
Unanswered	2

If yes, please comment on the reason behind your reservations:

animal research
it depends on the nature of the information
Given that nature of the industry-academic collaboration, there is Intellectual property sensitivity around some emerging research areas

24. Do you feel that your institute website is a good representation of the research conducted in the institute?

Yes	10
Somewhat	5
No	0
Unanswered	2

I welcome any additional comments you may wish to add:

We are beginning our process to redesign our research website.
Our website is sadly out of date, so we are currently recruiting for a communications officer to take on this responsibility for us. Once hired, the first priority for this person will be to totally revamp our website.
#16 donors and potential donors are important audiences for our website, as well as members of our Board of Trustees.
The website was recently updated to reflect the dynamic nature of research within the Institute. There is not a full-time dedicated resource to the site, in an ideal funding scenario this would be the case! The site updates lie within the E & O team and updates happen on a bi-weekly basis. We believe the website acts as an opportunity for many of our stakeholders to find out more about us, but also as a method to get in touch with us.
While we know how important our website is, staff resources prevent us keeping it as up to date as we would like. We know our website could be improved.

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