In search of models: An investigation into the practical use of models of science communication in science journalism production

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ABSTRACT

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Elyse Amend

The objective of this study was to investigate the practical use of science communication models in science journalism production. While research has reiterated critiques of science journalism's quality, theoretically-supported solutions have yet to be suggested. The results of this project seek to address this gap and inform the development of clear criteria against which the quality of science journalism can be tested. Existing literature has examined various models of science communication, but has largely been limited to theoretical discussions. This thesis developed and tested criteria for the applied use of theoretical models of science communication, essentially asking *how* these models could be put to practice. Using a grounded theory approach, this project was undertaken in four phases: 1) story-writing guidelines based on four models of science communication were developed; 2) science journalists were recruited to write "test stories" based on the four models; 3) journalists were interviewed on their interpretations and applications of the guidelines; 4) focus groups were held to gauge reader response to the "test stories." This approach generated four major findings: 1) model-based story guidelines can be put to practice; 2) participating science journalists largely maintained usual practices despite some guidelines calling for non-traditional story-writing methods; 3) audience members gravitated toward non-traditional approaches; and 4) science journalists' perceptions of their imagined audiences require increased clarification. These results were synthesized to propose a preliminary theoretical framework for a hybrid model of science journalism that is audience-centred and responds to critiques by promoting engagement through appealing to actions.

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INTRODUCTION

While some research suggests science journalism is of good quality (Bubela & Caulfield, 2004; Caulfield, 2004; Peters et al., 2008), much of the literature has repeatedly pointed to failures of science journalism, claiming the work of journalists is often inaccurate, sensational, lacking or oversimplified in methodological details, and fails to engage audiences in meaningful debate about scientific issues (e.g. Holland et al., 2011; Dentzer, 2009; Bubela et al., 2009; Racine et al., 2006; Russell, 2006; Logan, 2001; Weigold, 2001; Nelkin, 1995). However, while the literature continues to reiterate the same critiques, and some research points to guidelines on best practices in science reporting (e.g. Bostian, 1983; Levi, 2003; McBride et al., 2007), these guidelines have not offered 'clear' criteria of use for working journalists, for example, in terms of showing and ***theoretically*** defending how guidelines functionally relate to the production of a particular print science story. This gap is in part due to a lack of clearly articulated standards that are supported by theoretical considerations of the varying purposes of science communication[1], which can thereby be used to evaluate science journalism.

The presented study asked: Can models of science communication be put to practical use in the production of science journalism to help address current critiques? Using a grounded theory approach, this question was investigated by building on limited

[1] In this text, "science communication" is referred to as the academic discipline as well as activities that aim at communicating science to non-scientists. "Science journalism" is referred to specifically as the craft practiced by journalists. Historically, much research has focused on science communication, which this project draws on for contextual background. However, the focus here is on science journalism as a subset of science communication research.

past research that has applied science communication models to journalism practice (Secko, 2007), and then by investigating how such applications are experienced by both journalists and members of the general audience. This approach addressed the identified gap in the literature by articulating and testing how the links between theory, practice and experience are related to criteria against which the quality of science journalism can be tested.

Introductory literature review: Critiques and obstacles to science journalism

The importance of science journalism as a form of communication that can allow people to keep themselves apprised of scientific developments, assess the value of research, and make judgements related to their environment, health and well being (Nelkin, 1995) has long been debated by scholars, scientists, and journalists. The debate centres around how science journalists can best turn scientific research into stories that are understandable, engaging, entertaining, and accessible to audiences that often do not have the scientific backgrounds to understand research in its original form. Recently, there has been a renewed urgency to thoroughly consider the field of science journalism (Secko & Smith, 2010; Bubela et al., 2009; Dentzer, 2009; Logan, 1999), as some scholars have called for increased engagement among publics in the governance of emerging scientific technologies (cf. Burgess & Tansey, 2009). New societal questions are emerging as the pace of scientific research accelerates, while science also becomes more global, interdisciplinary and privately funded. For example, in fields such as genomics, genetically modified crops, and biofuels, a multitude of issues have been raised, including privacy, consent, food security, global health disparities, and genomic sovereignty (Amend & Secko, 2011; Amend & Secko 2010). However, during a time of increasing demand for digestible science information, science journalism has been criticized as unable to deal with the complexities of modern scientific debates. Science journalists have been charged with uncritical reporting (Racine et al., 2006), for emphasizing frames of scientific progress and economic prospect (Nisbet & Lewenstein, 2002), for having preferences towards positive scientific messages (Cassels et al., 2003), for not presenting a range of expert opinion (Holtzman et al., 2005), and for reporting unrealistic timelines and engaging in the production of a "cycle of hype" (Bubela et al., 2009; Caulfield, 2004). Other criticisms indicate oversimplification and extrematisation in science journalism lead to the distortion of scientific research and findings (Nelkin, 1995). Additionally, focus on controversies in science stories, exclusion of scientific details such as methodological specifics and the use of "binary oppositions" to simplify complicated stories and represent objectivity have been noted as qualities of poor science journalism that impede the creation of knowledge and instead lead to confusion and apathy among audiences (Boyce, 2007).

While challenged with such criticisms, journalists covering science are also faced with numerous obstacles in their day-to-day work, such as their own level or lack of science education (Ward & Jandcui, 2008; Saari et al., 1998; Hansen, 1994), structural and editorial constraints, such as working with strict deadlines and decisions imposed on journalists by their editors and/or media outlets (Ward & Jandcui, 2008), as well as economic realities in the news media industry. Less money is being allotted to covering in-depth science stories, and there are fewer journalists, including specialist science reporters, in newsrooms (Brumfiel, 2009; Ward & Jandcui, 2008; Russell, 2006). A meta-synthesis of the qualitative literature focusing on health and science journalists' lived experiences (Amend & Secko, 2011) also found that time and deadline pressures, finding and contacting reliable sources, lack of space for health and science stories, news media industry realities such as budget and staff cuts, and competition and commercialization were the main constraints discussed by health and science journalists. As journalism increasingly moves toward the internet – where competition for audiences is even higher – science journalists are expected to be multi-skilled with numerous digital platforms (Allan, 2009) and are asked to do more in less time and with fewer resources. Add to these obstacles an apparent communication and cultural gap between journalists and scientists, (Reed, 2001; Boyce, 2007), ambiguity over what science journalism and journalists' roles are, (Saari et al., 1998; Hansen, 1994), and uncertainty about who audiences of science journalism are and how they use science news to gain knowledge (Saari et al., 1998; Treise & Weigold, 2002).

While the extent and impact of the above critiques remains contested, they are nevertheless important when viewed against theoretical arguments that science journalism should inform audiences so they can keep track of new developments in science, understand and assess the strength of scientific research, and make informed decisions about competing scientific arguments (Nelkin, 1995). It is also argued science journalism should equip audiences with the knowledge and understanding to make personal decisions related to their safety, health and environment. However, although much of the existing literature suggests science journalism is not living up to its purposes, research has yet to offer concrete practical solutions to journalists to help counter these criticisms. The literature further lacks clarity on the theoretical underpinnings that can be used to support any proposed solutions to current criticisms. The importance of science journalism thereby necessitates research that seeks to tie theory to practice in support of clearly articulated standards.

Theoretical approach to the overall problem and rationale[2]

Theoretical models of science communication can be useful for conceptualizing how journalists do, as well as might produce science journalism, and thus provide a basis to help bridge the gap between theory and practice by offering the ability to actively work towards broader frameworks against which the quality of science journalism can be tested. There is a rich philosophical and empirical literature (e.g. Brossard & Lewenstein, 2010; Logan, 2001; Weigold, 2001) that can help define models against which science journalism can be judged. A "model" can be defined as a representation of one thing by something else, for example through analogy or metaphor (Leach et al., 2009). As Leach et al. (2009) explain: "Models may be made to help us remember things, help us imagine things or interactions we cannot see, explain situations or test phenomena that are not easily or directly testable" (Leach et al., 2009).

This research focused on developing story production criteria based on four models of science communication (further described in Chapter 1): the science literacy, contextual, lay-expertise, and public participation models (Brossard & Lewenstein, 2010; Logan, 2001; Weigold, 2001; Secko, 2007) and attempted to bridge the gap between theory and practice by directly involving working journalists in testing the use of these

[2] This theoretical approach is based on the science communication and science journalism literature, but also informed by audience theory (Hall, 1993; Morley, 1993) and the wider emerging field of journalism studies (e.g. Wahl-Jorgensen & Hanitzsch, 2009).

models, as well as gauging reader response to developed test stories through audience member focus groups. This project was limited to four chosen models due to (1) the desire to provide a focused and limited set of models for analysis; (2) practical time considerations; and (3) the fact that the chosen models represent both the dominant classical and contemporary models of science communication, as well as elements such as societal and cultural contexts and local "lay person" or "stakeholder" knowledge that is often lacking in science coverage (Brossard & Lewenstein, 2010; Secko, 2007).

Research design and specific aims

The overall objective of this research was to investigate how four models of science communication can be applied to the production of science journalism in order to gain an improved understanding of how theory-practice divisions can be broached. The models were examined by employing a unique adaptation of Secko's (2007) "test stories" methodology, which involved interviews with journalists recruited to write test stories, and focus groups to gauge audience reception. Importantly, the presented study charts new territory by moving away from Secko's (2007) focus on guideline development and Brossard and Lewenstein's (2010) focus on mapping models onto particular cases of science communication, to a focus on how journalists and audience members experience such communication modelling. By gaining insight into journalists' experiences using the models and their associated criteria to write journalism, the research shed light on how journalists functionally make use of a particular model and hence how science journalism is produced from within various theoretical boundaries. Additionally, by investigating audience reception of the stories, this research shed light on how audience members differently engaged with each science communication model and used it to gain knowledge and understanding.

The thesis was undertaken in four phases, which are detailed in Chapters 1, 2, 3 and 4. Qualitative analysis and a grounded theory approach were used throughout the study. A qualitative approach was chosen for its strengths in investigating the meanings research participants attach to events, actions, relationships or social phenomena, and in recognizing associated trends (Maxwell, 1996). A grounded theory design was seen as appropriate due to its strength in moving beyond description of data to identifying new theories for processes that are thus far unexplained (Creswell, 2007; Corbin & Strauss, 1990). The specific aims of this thesis and the chapters in which they are addressed include:

1. Development of story-writing criteria to allow the applied journalistic use of the four chosen models of science communication (Chapter 1).
2. To recruit professional print journalists to write "test stories" on complex and timely scientific issues -- specifically genomics and bioengery -- by making use of the criteria developed in aim 1 (Chapter 2).
3. To interview these journalists on their experiences writing the test stories and examine their interpretations of the guidelines developed in aim 1 (Chapter 3).
4. To conduct focus groups with members of the "general audience" in order to gauge reader response to the test stories written in aim 2 (Chapter 4).
5. To synthesize the results from aims 1-4 and propose a preliminary theoretical framework for the improved assessment of the quality of science journalism from within different theoretical frames (Chapter 5).

CHAPTER ONE – Connecting models of science communication to story production criteria: building bridges between theory and practice in science journalism

Historically, science communication research has considered various models of science communication. The most dominant have been "deficit" models concentrated on filling audiences' perceived knowledge gaps on a given subject (Brossard & Lewenstein, 2010), or those focusing on increasing scientific literacy and public understanding of science (Gerhards & Schäfer, 2009; Logan, 2001). Less dominant contextualized models (Brossard & Lewenstein, 2010; Gerhards & Schäfer, 2009; Donghong et al., 2008) have sought to tie scientific information to particular contexts and communities, as well as to increase the value of forms of knowledge outside of science (Brossard & Lewenstein, 2010; Donghong et al., 2008). Recently, the literature has begun to address models that seek to encourage public participation, engagement, and interactivity with science and reinforce meaningful debate in support of democracy (Brossard & Lewenstein, 2010, Secko, 2007; Logan, 2001).

This recent interest in more diverse models of science communication is in part due to suggestions that traditional models dominant in scientific communication, such as deficit and science literacy models, may be too narrow to deal with the complexities, rapid diversification, and debates of modern science (Secko, 2009). For example, Leach et al. (2009), analyzed a classic transmission model (which focuses on three elements: the sender/producer of the message, the message and its contents, and the receiver/audience of the message) and a ritual model (which concentrates on the communal experience of sharing information in a particular context) in the context of science literacy. Leach et al.

(2009) concluded that in order to improve communication and "clarify issues, change the tenor of the debate, and focus on more communication issues in order to make everyone's interests in the situation clear" (p. 136), new models of science communication must "take into account the many and varied agents involved in the communicative process, addressing the motivations and constraints of the institutions, discourse and communities thereof, the context of the communicative act, and so on" (p. 144). Logan (2001) has also tracked the evolution of what he terms the classical model of science communication (which focuses on scientific literacy and has more pedagogical attributes) as related to what he terms the interactive model (which focuses less on teaching people and more on actively engaging groups such as "citizens, scientists, politicians, government and corporate officials, and journalists" in the science communication process in order to improve communication among these groups). Logan (2001) argued that new models of science journalism should make use of the overlapping features of the classical and interactive models in order to supplement traditional practice with new approaches to science communication (p. 157-158).

More recently, Brossard and Lewenstein (2010) analyzed four models of communication related to the public understanding of science: 1) the deficit model, which views the public as lacking knowledge; 2) the contextual model, which recognizes different people receive information in different ways or contexts that determine their responses to the information; 3) the lay-expertise model, which argues "local knowledge" based in the lives and histories of communities may be as valuable as scientific knowledge, and aims at empowering local community; and 4) the public engagement model, which places emphasis on seeking public input and democratizing the scientific process (Brossard & Lewenstein, 2010). Brossard and Lewenstein (2010) mapped these four models on to four cases of science communication as part of the ELSI Outreach Programs related to the Human Genome Project to investigate whether the models reflected reality. In their analysis, they argued the four models do not capture the full reality of science communication activities, in part because such activities tend to use mixed approaches from a number of models, rather than resting strictly within any one individual model (Brossard & Lewenstein, 2010).

Each of these examples highlights that we have yet to fully define a robust science communication model that could help researchers better understand the practice of science journalism. Furthermore, much of the research has considered models of scientific communication solely under a theoretical lens, and has not examined how they can be put to use in a real-world, practical context. Thus, there exists a gap between theory and practice that, only recently, research on science communication has begun to consider. The use and further development of such models is valuable, as having clear representations of how science journalism is produced and experienced by journalists and audience members can provide the theoretically-informed but practical frameworks needed to give more nuanced evaluations of the quality of science journalism, and thereby provide guidance on how recurring critiques of the craft may be answered.

There are a limited number of studies that provide guidance on how to effectively bridge the theory-practice divide in science journalism. Brossard and Lewenstein's (2010) study as discussed above is one example, however this research only examined how existing cases of science communication fit into their described models, and not how the models can be practically used in the production of science journalism. In other words, some research has investigated how certain cases map onto certain models, but has not expressly defined functional criteria for these models that could be used to replicate the cases under varied circumstances. Nor have they tested the models in "live" circumstances.

Research done by the *Concordia Science Journalism Project* (CSJP), which the presented study partially draws its inspiration from, has worked toward developing science journalism story criteria implied by models of science communication, specifically related to Logan's (2001) science literacy and interactive models (Secko, 2007). This research has attempted to link these theoretical models to the craft of science journalism by drawing on the scholarly literature and 15 personal interviews to develop 13 guiding principles (Secko, 2007). These principles contrasted the use of the science literacy model versus the interactive science model for print journalism production, and were employed to write test news stories by the researchers. Limited published data from this study indicated that practical use of the interactive model holds promise, however it was also criticized on a technical level for being "eat your peas journalism" (Secko, 2007), thus suggesting further refinement of this model is needed to differentiate it from classical transmission models.

This study takes past research a step further by focusing on and developing science journalism story production criteria based on four models of science communication: the science literacy, contextual, lay-expertise, and public participation models. It begins by reviewing current discussion in literature as related to the models under investigation. Specific attention is then given to how the models may be put to practice in the context of science journalism story-production through the identification and conceptualization of six story criteria. The study concludes with the discussion of story-writing guidelines based on the four models investigated and their potential for future use by science journalists (further discussed in Chapters 2 and 3).

Method

Review of included models from a theoretical perspective

Models have been identified as useful tools in imagining, explaining and analyzing interactions, situations and phenomena that are otherwise not directly testable (Leach et al., 2009). Therefore, theoretical models of science communication were viewed as able to help conceptualize how journalists "do" science journalism and produce stories and, thus, were considered useful research tools for developing broader frameworks against which the quality of science journalism can be tested.

The four models investigated in this study represent both dominant classical and contemporary models of science communication. The **science literacy model** was selected as it represents traditional and common forms of science journalism seen in mainstream news media that seek to promote science literacy by transmitting expert knowledge to audiences perceived as having low or basic science literacy (Brossard & Lewenstein, 2010; Gerhard & Schäfer, 2009; Secko, 2007; Logan, 2001). Although often critiqued as being a more refined form of the science literacy model (Brossard & Lewenstein, 2010), the **contextual model** was chosen as it follows the classic transmission model, however incorporates such elements as societal and cultural contexts. The **lay-expertise model** was selected as a contemporary model that focuses on local knowledge and "lay-expertise," which have generally been disregarded in scientific research (Brossard & Lewenstein, 2010; Secko, 2007). Finally, the **public participation**

model was chosen as it is a contemporary model that places importance on including viewpoints of all "stakeholders" and promoting engagement with science (Brossard & Lewenstein, 2010; Secko, 2007) , and represents almost a 'polar opposite' of the science literacy model.

To supplement the key texts used as an initial defining point for each included model (Brossard & Lewenstein, 2010; Secko, 2007; Logan, 2001), detailed literature searches were completed in order to examine and review scholarship related to the models. The Academic Search Complete, Communication and Mass Media Complete, and Communication Abstracts databases were searched for peer reviewed literature using combinations of the following key words: science communication, models, theory, theoretical, deficit, science literacy, context, contextual, lay-expertise, lay-people, lay-person, public, participation, engagement, interactive. The searches retrieved 12 relevant articles (Bubela, 2006; Clarke, 2003; d'Andrea & Declich, 2005; Davies, 2008; Gerhards & Schäfer, 2009; Kahlor & Rosenthal, 2009; Kerr et al., 2007; Kouper, 2010; Piolli & Conceição da Costa, 2008; Schweizer et al., 2009; Sturgis & Allum, 2004; Tlili & Dawson, 2010) that were used along with key initial texts (Brossard & Lewenstein, 2010; Secko, 2007; Logan, 2001) to determine the features and aims of the four models investigated (discussed further in the next section and summarized in Figure 1).

Development of story-writing criteria (practice perspective)

In developing story-writing criteria that could be tied back to the four models of science communication, it was taken into account that the guidelines were meant to be given to experienced working journalists with already-established personal journalistic routines and used in journalistic practice – specifically the story-writing process – and thus needed to be articulated in a way that moved beyond theory and related back to common practice. With this in mind, a review of the theoretical and practical literature relating to journalistic guidelines and story-writing criteria was done, with careful attention paid to the overlapping aspects and criteria. To begin, peer-reviewed literature on science journalism writing guidelines was investigated by performing database searches on the Academic Search Complete, Communication and Mass Media Complete, and Communication Abstracts databases using combinations of the following keywords: science, journalism, mass media, news, newspaper, story writing, story production, guidelines, best practices, strategies, criteria. Six relevant articles were retrieved (Bostian, 1983; Clarke, 2003; Foote, 2008; Rovira, 2008; Weigold, 2001; Zia & Todd, 2010). In order to broaden the scope of these searches, classic writing and reporting guidelines used in journalism education were consulted (Mencher, 2003), as well as guidelines particular to certain journalistic fields, such as peace journalism (Lynch, 2002), public/civic journalism (e.g. Glasser & Craft, 1997; Haas, 2007; Rosen, 1996), health and medical journalism (e.g. Vercellesi et al., 2010; Levi, 2003) and environmental journalism (e.g. Schweizer et al., 2009). Lastly, the development of story-writing criteria made use of an adaptation of Secko's (2007) method for developing 13 guiding principles for science journalism production. This method helped guide the analysis of the literature for overlapping features to suggest more refined guidelines that were ultimately conceptualized into six story-writing criteria. These criteria were specifically tied to the features and goals of each model under investigation, which are described in the next section.

Findings: Brief review of the four models of science communication under investigation

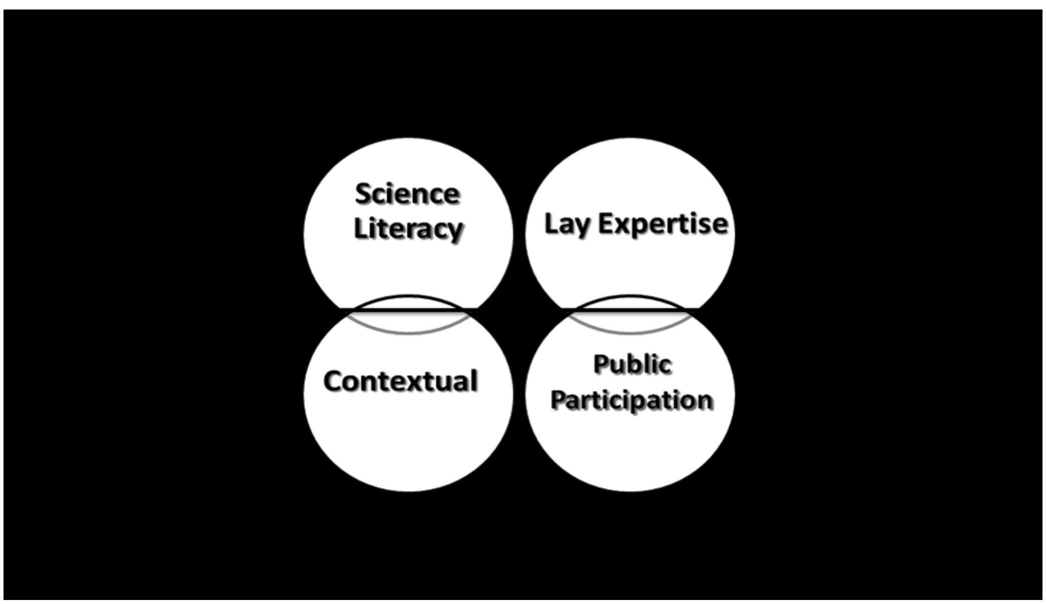
Science literacy model

The science literacy model's goal is to essentially "translate" scientific information for publics in order to give citizens the information needed to make decisions in their daily lives, as well as gain popular support for science (Secko, 2007). It is a pedagogically-oriented model that focuses on raising science literacy, or the level of understanding publics have about science (Brossard & Lewenstein, 2010; Gerhard & Schäfer, 2009), and treats science as fixed and certain (Brossard & Lewenstein, 2010), in that the scientific method and process is what justifies the knowledge presented and is thus not questioned (Nelkin, 1995; Leach et al., 2009; Figure 1). From a journalistic perspective, the use of the science literacy model involves employing traditional journalistic norms, such as objectivity (Secko, 2007), and viewing audiences as lacking knowledge on a topic in question. The model therefore assumes a "top-down" linear transmission structure to deliver information and knowledge provided by scientists to the journalists, who in turn "translate" the research and scientific information into news stories that are accessible and understandable for their audiences (Brossard & Lewenstein, 2010). The science literacy model has been criticized on a number of levels, including lack of context and a failure to connect scientific information to personal relevance, uneven power relations between those viewed as having knowledge (science) and those that do not, as well as ignorance of other forms of knowledge outside of science (Brossard & Lewenstein, 2010).

Contextual model

While the contextual model employs a traditional “top-down” linear transmission structure similar to the science literacy model (Brossard & Lewenstein, 2010), it goes a step further by addressing scientific information in specific, audience-linked contexts (Figure 1). The contextual model takes into account that science may mean different things in different geographic and social locations (Donghong et al., 2008). It acknowledges that individuals receive information in particular contexts , influenced by such things as personality type, personal psychology, social settings and relationships, that shape how the information is processed and responded to (Brossard & Lewenstein, 2010; Kahlor & Rosentahl, 2009).

Figure 1: Theoretical models of science communication
-- adapted from Brossard & Lewenstein (2010, p. 17, 33)



The contextual model also reflects the encoding/decoding model discussed by Hall (1993, in During, 1999), who suggested media messages are “encoded” with the social, political, economical, organizational etc. contexts they are created within, and then "decoded" by audiences and attributed meaning tied to the personal and social contexts they are interpreted within (pp. 507-517). From a journalistic perspective, the use of the contextual model implies the construction of messages that are relevant to particular audiences while paying attention to the needs and situations of these audiences, for example by using modern marketing segmentation to identify populations with different attitudes toward science or putting context-specific questions to the experts (Brossard & Lewenstein, 2010). While some research has suggested the contextual model theoretically maintains a "more open and two-way relationship between 'the sciences' and 'the publics'" (Irwin, 2009, pp. 7-8) while perceiving "the audience" as being able to quickly gain knowledge about relevant topics (Brossard & Lewenstein, 2010), it has also been critiqued as being just another version of the deficit model, as it maintains a "top-down" linear transmission structure that places scientific knowledge above other forms of knowledge. As Donghong et al. (2008) state: "[T]he contextual model, while more nuanced than the deficit model, shares the same premises: first, science and society are conceived as two autonomous spheres, distinct from one another, and with one prevailing over the other; second, only a mastery of techniques and communication enable a rapprochement and the regaining of equilibrium" (p. 2).

Lay-expertise model

Much of the literature does not specifically define the lay-expertise model, and instead views it as a refined version of the contextual model (e.g. Allan, 2009; Kahlor & Rosentahl, 2009). However, Brossard and Lewenstein (2010) define the lay-expertise model as distinct. The main separating factor is that the lay-expertise model values knowledge in its own right and regards local knowledge to be as equally valuable as scientific knowledge. It is a "non-traditional" model that breaks with the "top-down" conception of the science-society relationship, and incorporates the knowledge and concerns – or "lay-expertise" – of specific populations (Donghong et al., 2008; Figure 1). It views science as limited and uncertain, and accepts expertise from sources outside of science (Brossard & Lewenstein, 2010). The overall goal of the lay-expertise model is to empower local communities by fostering confidence that individuals have valuable knowledge to share and can participate in the scientific process (Brossard & Lewenstein, 2010). In journalistic terms, the lay-expertise model focuses on alternative perspectives outside of scientific expertise and examines questions related to values, ethics and society not usually considered by more traditional models (Gerhard & Schäfer, 2009, p. 448).

As other models of science communication, the lay-expertise model has its share of critiques. For example, it has been criticised for being "anti-science," as it privileges non-scientific knowledge, as well as not necessarily raising public understanding of science in order to provide practical guidance (Brossard & Lewenstein, 2010, p. 15).

Public participation model

The public participation model attempts to make the scientific process more interactive and encourage public debate surrounding scientific issues. Thus, it focuses less on teaching people or filling a knowledge gap and more on actively engaging stakeholder groups -- such as citizens, scientists, journalists, politicians, business people, government officials, etc. -- in the science communication process. The model does this with the aim of improving communication and trust among these groups (Logan, 2001). As with the lay-expertise model, the public participation model is "non-traditional" in that it breaks with the "top-down" linear transmission structure present in mainstream journalism. The public participation model emphasises the democratization of and public participation in the scientific process, especially regarding policy issues that involve scientific knowledge (Brossard & Lewenstein, 2010; Figure 1). According to Brossard and Lewenstein (2010), this can potentially be achieved on three levels: (1) simple interactions between citizens and scientific experts, (2) citizens' empowerment, and (3) actual public authority over policy (p. 33). In journalistic terms, the public participation model focuses more on the processes behind the science and the inclusion of a multitude of stakeholder viewpoints, and aims at engaging audiences in a pluralistic debate. The public participation model has been subject to criticisms as well, such as addressing politics and policy issues over public understanding of science and emphasising the process of science while discounting the actual content, as well as only being able to address smaller, particular audiences at a time (Brossard & Lewenstein, 2010).

Story-writing criteria development

While it is clear from the above descriptions that each model has been viewed both positively and negatively, they have yet to be adapted for practical use by journalists, for example through the development of story-writing criteria that are directly implied by each model. This means we lack understanding of how theoretical models of science communication may be put to practical use in science journalism, and consequently are missing an opportunity to make use of them to inform clear criteria against which the quality of science journalism can be judged. This paper therefore turns its attention to the conceptualization of the story-writing criteria that can be tied back to the four models under consideration.

In reviewing the literature on journalistic story-writing guidelines, it became clear there existed five overlapping themes. These themes were used to conceptualize five story-writing criteria to be applied to the models, described below (Table 1). A sixth criterion focusing on the positioning of science in news stories was also formulated specifically for the context of science journalism. These six criteria are explained in turn.

Table 1: Story-writing criteria

1. Purpose	Why is the story being written?
2. Focus	What is the story about? What is the focal point of the story?
3. Style	How is the story written?
4. Sourcing	Which voices does the story include?
5. Audience	Who is the story written for (and what role do they play)?
6. Science	How is science portrayed?

Purpose

This criterion emerged firstly out of traditional journalistic writing and reporting guidelines commonly used in journalism education (e.g. Mencher, 2003), which referenced traditional values, such as informing, accuracy, fairness, balance, and objectivity, as driving principles behind journalistic story-writing. Guidelines tied to particular journalistic fields, such as peace journalism, also referenced the journalist's perceived/implied roles -- such as educator, knowledge transmitter, storyteller, and informer, among others -- as influencing the direction a story takes and thus driving its purpose (Lynch, 2002). Secko (2007) also identified "purpose" as a guiding principle in science journalism production, with the transmission model's purpose being the transmission of information, and the engagement model's purpose suggested as promoting “active engagement and education in support of democracy” (p. 33). Thus, this criterion asks journalists to think about why the story is being written?

Focus

Traditional journalistic writing and reporting guidelines (e.g. Mencher, 2003), as well as basic science journalism guidelines (Lublinski et al., 2008) offered recommendations on how to focus news stories, mainly by using traditional news values, such as timeliness, impact, currency and conflict – to identify the focal point of a given news story. Other guidelines in health reporting (e.g. Vercellesi et al., 2010) and environmental journalism (e.g. Schweizer et al., 2009) suggested the focus of a given news story should be tied to particular contexts, such as the scientific, cultural, social, and political issues that tie in to the story, or what situation or place the story is situated in (Schweizer et al., 2009). In his guidelines for peace journalism, Lynch (2002) suggested journalists focus stories by asking such questions as whether the story is event-based, or whether it seeks simplicity or to explore complexity. Secko (2007) also referenced “focus” as a guiding principle, for example with deficit model stories focused on events and publication, and engagement model stories focused on the consequences of choices made (p. 33). Thus, this criterion asks journalists to consider what the story is about and what the focal point of the story is.

Style

Style was also a principle for journalistic story-writing consistently referenced in the literature. Basic journalistic guidelines, as well as those focused more on science, health and environmental reporting (e.g. Lublinski et al. 2008; Vercellesi et al., 2010;

Levi, 2003; Schweizer et al., 2009) referenced traditional journalistic or information delivery styles[3] that seek to inform audiences about science by translating scientific research and information into simple language that avoids jargon and explains complex scientific concepts by using analogies and metaphors. However, stories written according to non-traditional models may need to reconsider such traditional journalistic styles and adapt non-traditional styles that go beyond solely transmitting information, or 'reporting the news', and innovate more 'holistic' style techniques that address a range of stakeholders' interests and seek to promote active public engagement. Thus, this criterion asks journalists to consider how the story is written.

Sourcing

Sourcing was commonly referenced in the literature as guidelines on determining what information is to be included in a news story, as well as whose voices are to be heard. While basic guidelines covered the number of sources to include in a given story -- i.e. at least two in order to portray journalistic balance (Lublinski et al., 2008) -- and leaned towards valuing expert sources over others, other guidelines for such fields of

[3] Such a style is reflective of the "transmission" view of communication that focuses on sending or giving information to others (Carey, 1989, pp.14-15). It is a linear model of communication that has three main components: the sender, the message that is being sent, and the receiver of the message (Carey, 1989). For example, under this model, journalists are considered the senders of the message, the newspaper articles they write are considered the message, and the readers are considered the receivers of the message (Leach et al., 2009, p. 138). The transmission model that largely characterizes journalistic story-writing style assumes that if the sender and message components in this linear transmission can be improved, then the reception of the message and receiver understanding of the information contained it is will also be improved (Carey, 1989; Leach et al., 2009, pp. 131-133, 136).

journalism such as public/civic journalism (e.g. Glasser & Craft, 1997; Haas, 2007; Rosen, 1996) advocated the inclusion of additional sources and voices outside of experts (such as community members and leaders, organizations, employees, and so on) to aid in improving issues of representation and civic participation, and shift from a "journalism of information" to a "journalism of conversation" (Glasser & Craft 1997, p. 124) in order to create discussion, promote participation, aid in problem-solving, and re-connect people to civic life (Rosen, 1996, p. 13, 85).

Although not termed "sourcing," Secko's (2007) guiding principles also looked at how knowledge was legitimized in science stories, such as through scientific information itself in the case of the deficit model, and through personal knowledge in the case of the engagement model (p. 33). Thus, the sourcing criterion asks journalists to consider what information and which voices are included in the story.

Audience

Literature on fields of journalism such as the civic/public journalism movement (e.g. Glasser & Craft, 1997; Haas, 2007; Rosen, 1996) and peace journalism (Lynch, 2002) pay particular attention to the audience, in that they ask journalists to consider who exactly they are writing for, as well as whether the audience plays a passive or active role in the story-selection and production phases themselves. Similarly, Schweizer et al. (2009) suggested journalists include the audiences' interests, values, cultural beliefs and actions in considerations over climate change coverage, as this can help readers connect to the story, make meaning of the story's message, and give audiences a sense of empowerment in knowing what they can do to make a difference (p. 271-272). Thus, this criterion asks journalists to consider who the story is written for and what role (if any) audiences play in the story-production process.

Science

Although the science criterion was not an issue consistently represented across journalistic story-writing guidelines, it was deemed a necessary consideration to fully capture the essence of each model. For example, while the "traditional" models (science literacy and contextual) view science as fixed and certain -- in that the scientific method and process is what justifies the knowledge presented and is thus not questioned (Nelkin, 1995; Leach et al., 2009) -- the "non-traditional" models (lay-expertise and public participation) view science as uncertain and socially bound (Brossard & Lewenstein, 2010; Secko, 2007). The 'science' story-writing guideline seeks to clearly define these differences between models. This criterion thus asks journalists to consider how science should be portrayed in the story.

Linking models to story criteria

As the story-writing criteria were intended to be used by working journalists in the production of science journalism articles based on the four models of science communication researched in this project, the six criteria and models were linked together in guidelines articulated in a concise "how-to" guidebook form. The result is described for each model below.

In keeping with the science communication literature's definition of the science literacy model's purpose as informing and promoting science literacy (Logan, 2001; Brossard & Lewenstein, 2010), a story written according to this model should have its main purpose as informing audiences about the scientific aspects of a research project/story. Thus, the model implies that journalism created within its framework should attempt to focus on specific events and publications, while making use of conflict or novelty (i.e. the science's "wow" factor) to tell a story (Box 1). As the purpose of a story based on the science literacy model is to inform audiences and promote science literacy, such a story should be written in a classic journalistic or traditional information-delivery style that seeks to "translate" scientific research and information into understandable and accessible stories transmitted to audiences, using scientific experts as the main sources and treating readers as a passive audience. Science is viewed as fixed and certain (Nelkin, 1995; Leach et al., 2009) and expert knowledge is valued over other forms of knowledge as the main legitimizing factor (Brossard & Lewenstein, 2010; Secko, 2007).

Box 1: Journalist guidelines: Science literacy model

Purpose: The story should be written in order to inform the audience about the project and/or the science.
Focus: The story should focus on events, publications (i.e. journal articles or public relations) and may be driven by conflict or the science's "wow factor."
Style: The story should be written in a traditional information-delivery style.
Sourcing: The story's main source(s) should be official experts and/or documents.
Audience: The audience should be treated as spectators. Audience members should have no direct involvement in the story.
Science: Science should be viewed as fixed and certain. Expert knowledge is valued over any other form of knowledge.

The contextual model seeks to inform communities and individuals about science as it relates to their particular contexts (Brossard & Lewenstein, 2010; Kahlor & Rosentahl, 2009; Donghong et al., 2008). The purpose of a contextual model-based science story is therefore to seek to inform audiences about the science as it relates to them (Box 2). While not abandoning scientific description, this necessitates a stronger focus on issues and aspects of a science event that relate directly to the audience or a given community by tying the messages and information in the story to the personal and social contexts they will be received and interpreted within (Hall, 1993, in During, 1999). As the purpose of a contextual model story is, like the science literacy model, mainly to transmit information and knowledge about the science to audiences, a contextual model story should also be written according to a traditional journalistic or information delivery style. Scientific experts are again used as the main sources, as science itself is the legitimizing factor behind the information and knowledge presented. As the main purpose of a contextual model story is to inform audiences about the science as it relates to them, community members or other "non-experts" may also be used as sources, but only to provide background information and context to help journalists in constructing messages that relate to the contexts in which they will be received. However, as contextual model stories adhere to a traditional information-delivery style, audiences do not have any direct participation within the story itself.

Box 2: Journalist guidelines: Contextual model

Purpose: The story should be written to inform the audience about the science as it relates to them.
Focus: While reporting on the science, the article should focus on events, issues, concerns, cultures, beliefs, and realities specific to particular population(s) and may be driven by a community dilemma to which science can provide answers.
Style: The story should be written in a traditional information-delivery style.
Sourcing: The story's sources may include community members, community leaders, organizations, etc. to provide background/context and the main questions. Expert sources may be used to provide answers.
Audience: The story should be aimed at audiences affected by the science. Audience participation should be limited to "concerned/questioning spectators" (i.e. the audience provides context and questions).
Science: Science should be viewed as fixed and certain, with the experts seen as able to provide answers to the community's questions and concerns. Issues are legitimized through science.

As with the science literacy model, science should be viewed as fixed and certain, with the experts treated as able to provide answers to the community's questions and concerns.

The lay-expertise model values local knowledge as much as, if not more than, scientific knowledge and seeks to empower local communities in the scientific process (Brossard & Lewenstein, 2010; Irwin, 2009). Thus, a story written according to the lay-expertise model should aim at empowering local communities in the scientific process and promoting engagement in democratising the scientific process, and focus on the community's attitudes towards the science and issues related to/stemming from the science (Box 3). Such an article may be driven by a community dilemma with the community seen as able to provide solutions.

Box 3: Journalist guidelines: Lay-expertise model

Purpose: The story should be written to help empower local communities in the scientific process and promote engagement in democratising the scientific process.
Focus: The article should be based on the community's attitudes towards the science and related issues. It should focus on local knowledge and may be driven by a community dilemma with the community providing answers.
Style: The story should be written in an "active engagement" style that considers and validates knowledge outside of science.
Sourcing: The main sources for the story should be lay-people, community members, community leaders, organizations, etc. Scientists should not be treated as the only "experts," and scientific information in the article should be limited to background/context.
Audience: The story should be aimed at audiences affected by the science. Audience input is sought after (in the form of knowledge and viewpoints).
Science: Science should be treated as uncertain. Personal and local knowledge is the legitimizing factor. Science is not valued over other forms of knowledge.

As the lay-expertise-based story seeks to validate knowledge outside of science and empower communities in the scientific process, traditional linear information delivery styles may not be appropriate in representing this. Thus, such a story should step away from a traditional journalistic style that seeks to solely transmit scientific information to audiences and adopt a style that reflects “active engagement” of lay-people and community members in the scientific process by including voices and sources of information outside of science (Donghong et al., 2009). Thus, the story’s main sources should be community members and lay-people, with the story seeking and valuing input from the particular audiences it is aimed at. Additionally, in order to reflect this emphasis on lay-expertise and local knowledge, scientists and experts should act as secondary sources, with their roles limited to providing background and context (Brossard & Lewenstein, 2010). Unlike the science literacy and contextual models that justify knowledge and information with the scientific method and process and thus do not question it (Nelkin, 1995; Leach et al., 2009), a lay-expertise model-based story does not value science over any other form of knowledge and correspondingly should treat is as uncertain, with personal knowledge as the legitimizing factor (Brossard & Lewenstein, 2010).

As the public participation model aims to promote active engagement from all stakeholders and democratise the scientific process (Brossard & Lewenstein, 2010), as well as improve communication and trust among these groups (Logan, 2001), the purpose of a science news story based on this model should go beyond reporting the news and promote active engagement, and may thus focus on such issues as the processes behind the science, as well as the consequences of the choices made (Box 4). As traditional journalistic styles may not effectively reflect such a purpose, the public participation model-based story should take on a style that goes beyond information delivery, and instead maps viewpoints and opinions of the stakeholders involved in a communal fashion and promotes channels for more active, non-linear discussion (Brossard & Lewenstein, 2010). Consequently, sourcing should include as many implicated groups as possible, including audience members, whose opinions and viewpoints are sought after in the story. Finally, as with the lay-expertise model that accepts knowledge away from science, science in a public participation-based story should be treated as uncertain and embedded in society (Secko, 2007).

Box 4: Journalist guidelines: Public participation model

Purpose: The story's purpose should go beyond telling the news and promote active engagement (in the scientific process) and education in support of democracy.
Focus: The story should focus on the process behind the science, as well as the consequences of the choices made. The story may be driven by a dilemma for the community that needs all voices to be solved correctly (which can include the community, experts, audience, journalist, etc.).
Style: The story's style should focus on mapping the viewpoints/opinions of the stakeholders involved in a communal fashion.
Sourcing: All stakeholders should be explored and sought as possible experts. Scientists and other official experts are not presented as "special" or more knowledgeable than anyone else.
Audience: Audience members should be considered stakeholders, and their input into the story should be sought after.
Science: Science should be presented as uncertain and embedded in society.

Discussion

Research has suggested overlapping features of traditional and contemporary models of science communication should be used to supplement traditional practice with new approaches and inform new models of science journalism (Leach et al., 2009; Logan, 2001). Similarly, Brossard and Lewenstein (2010) argued that models of science communication require further refinement as they do not capture the full reality of science communication activities, because they commonly use mixed approaches from a number of models, rather than resting strictly within any one individual model. In order to advance research on the application of theoretical science communication models to science journalism practice, this project defined six story-writing criteria – purpose, focus, style, sourcing, audience and science – and applied them to four models of science communication -- science literacy, contextual, lay-expertise and public participation -- to produce story-writing guidelines to be utilized by journalists in the production of science news stories. This study was limited to four models due to practical time considerations; however the models chosen represented both the dominant classical and contemporary models of science communication and provided a focused analysis. Although some features of these four models do overlap, they were considered mutually exclusive due to each model's distinct purpose. In developing the model-based story-writing guidelines, none of the models were privileged over another or considered "better." Of course, the produced criteria and story-writing guidelines offer only a rough representation of the complex processes of science journalism. Thus, it is rather their application and the resulting model-based test stories produced by freelance science journalists discussed in the following two chapters that will further shed light on the effectiveness of the developed criteria and model-based guidelines, as well as the appropriateness of their application to science journalism practice.

CHAPTER 2 – Models in practice: Employing story criteria informed by theoretical models of science communication in journalism story production

While the literature on science journalism continues the report on the failings of the craft, criticising it for such shortcomings as inaccuracy and sensationalism, oversimplification and hype of scientific issues, and failing to truly engage audiences in meaningful discussions over science (e.g. Holland et al., 2011; Dentzer, 2009; Bubela et al., 2009; Racine et al., 2006; Russell, 2006; Logan, 2001; Weigold, 2001; Nelkin, 1995), clear guidance on how to improve science journalism that is both theoretically informed and can be applied to real-world journalistic practice has yet to be developed. This absence is due to the fact these conversations have largely remained theoretical without attempts to bridge the theory-practice divide by investigating how journalists functionally make use of such guidance.

Working with four models of science communication, this research seeks to address this gap by testing how practical, but theoretically informed, story-writing criteria are used by working science journalists. The story-writing criteria are seen as a research tool that can be applied to linking theory and practice in science journalism studies. The story-writing criteria were previously developed (see Chapter 1), but here are put into practice by four Canadian freelance science journalists, who were asked to produce test science news stories based on four sets of model-based criteria.

This chapter describes and analyzes the production of these test stories. It begins with an overview of how the science journalists were recruited and assigned the model-based guidelines they were to use in the production of their stories. Specific attention is given to how the six story-writing criteria developed in the previous chapter were represented in the produced stories. This chapter concludes with a preliminary analysis of what the criteria application might mean for the development of theoretical frameworks against which science journalism can be evaluated.

Method

Four Canadian freelance science journalists were recruited to write test stories based on the previously developed model-based guidelines (Chapter 1). Freelancers were chosen as they tend to write for numerous publications -- each with different styles, audiences, standards and editor expectations – and were believed to be better able and more willing to adapt their writings styles according to the diverse criteria investigated. In addition, newspapers in North America (as well as Europe) have been consistently cutting their science sections (Brumfiel, 2009), while the number of specialist science reporters with full-time jobs has steadily been dropping (Russel, 2006). Thus, it was assumed having freelance science journalists participate in this study would more accurately reflect the current state of the science journalism market in Canada. Finally, freelance journalists were chosen because of their availability, as they were assumed to not be as tied to daily deadlines and other time constraints.

Journalist recruitment took place during December 2010 and January 2011. Participants were required to have between 10 and 20 years of science journalism experience. In total, 18 Canadian freelance science journalists were contacted to see if they would be interested in participating in the study. Eleven turned down the offer due to time constraints and other obligations. Of the other seven, four met the recruitment criteria and chose to participate (three men and one woman; Table 2). Two had 10 years experience working in science journalism, while the two others had between 19 and 20 years of experience in the field. While all participating journalists had university degrees in the social sciences or humanities, only two had degrees in journalism. The other two participants learnt their journalism from experience in the field. Furthermore, while two participants did have some university science education, all four said most of their science learning originated from personal interest and activity.

Table 2: Freelance science journalist participants

FSJ#	Male/Female	Experience	Journalism degree	Science background
FSJ1	Female	10 years	Yes	Yes
FSJ2	Male	20 years	Yes	Yes
FSJ3	Male	10 years	No	No
FSJ4	Male	19 years	No	No

The journalists' participation in this research phase involved two stages:

1. A pre-interview, in which participants were asked to discuss their usual methods for writing science journalism news articles. The purpose of the pre-interviews was to gain insight into the participants' current practices in science journalism production and aid in effectively assigning the journalists the models to be used in writing their test stories. The pre-interviews lasted 30-60 minutes and took place between January 31 and February 2, 2011. They were done over the telephone and were audio-recorded. The interviews were semi-structured and utilized a number of open-ended questions focused on such topics as story selection, the story-writing process, the audience, their roles as science journalists, and the current state of science journalism. The interviews were transcribed and then analyzed using the coding software Nvivo 8 to judge which models the journalists' everyday practices fit with best and were least similar to in order to aid in assigning the two models each journalist would use to write their science news test stories.

2. The story writing phase, in which participants were asked to write two science news stories. Participants were assigned one traditional and one non-traditional model (see Chapter 1 and Figure 1). Participants were asked to situate themselves within the guidelines and follow them throughout the writing process as best as they could, as opposed to past experience and their usual approaches. Each story was required to be between 450 and 550 words long. All of the stories were focused on the same research project, namely a project on genomics and biofuels at Concordia University. Thus, all stories were to be about the same topic, but written differently depending on the models assigned. In addition to the project instructions and the model guidelines, the participants were given a background document on the research similar to a press release a journalist would receive (Appendix I). The participants were given approximately one month to write their two stories, with the eight completed articles submitted by March 13, 2011.

Each article was initially analyzed separately and compared against the story-writing guidelines developed in this project. During this process, the stories were analyzed to determine where elements of the story-writing criteria were represented, to what extent the journalists followed the guidelines, as well as where elements of the criteria seemed to be missing in the stories.

Journalists were compensated $500 each for their time and work. Data were analyzed using qualitative methods and a grounded theory approach. A grounded theory design was chosen for its strength in moving beyond description of data to building theory from data, and identifying new theories for processes that are thus far unexplained and to provide a general framework to explain how people experience certain phenomena

(Creswell, 2007; Corbin & Strauss, 1990; Corbin & Strauss, 2008). This study was approved by the Human Research Ethics Committee at Concordia University, and all participants were asked to give informed consent before participating in the study

Pre-interviews

In order to judge which models the journalists' usual routines and practices were most similar and most dissimilar to, the pre-interviews covered how the participants typically produced science journalism stories. Three major themes emerged out of the pre-interviews: story selection and production, imagined audience, and the perceived role of science journalism.

Story selection and production

Participants said they generally gathered story ideas through routes commonly used by science journalists (Gasher et al., 2007; Hodgetts et al., 2007; Roy et al., 2007; Hansen, 1994) -- such as press releases, other news outlets, and social media, for example – and chose which stories to write about according to personal interest. However, journalists said there was one main driving factor behind how they wrote their stories: the audience. Data from the pre-interviews suggest the participating journalists let what they perceive as their audiences' interests drive how they write and what information they include in their stories. One of the journalists interviewed compared how she would write the same story for two different audiences:

> It depends on the audience. So, if it was a business audience I would be using a lot of numbers and contracts and other very straightforward business practices. If it's more a science audience I would be focusing more on concepts. So, if I bring up insects, I would be talking about how grasshoppers actually do their calls, as for if it was a business audience, that wouldn't be something that would be so relevant. (FSJ1)

Similarly, a second journalist explained the readers' perceived interests are always present during the writing process:

> And then I'm a total writer, in the sense that I'm looking for the hook, looking for the lead. I'm looking for what's going to interest the lay-reader. (FSJ3)

Imagined audience

When asked how they pictured their audiences, all four participating journalists had answers indicating they saw themselves writing for audiences with very basic knowledge of science, using such descriptions as "early high school" level or a "person who had Grade 9 biology and didn't even attend the dissection class" (FSJ1), "a bright 12-year-old" (FSJ3), or having science understanding similar to that of "children" (FSJ4). With such perceptions of their "imagined audience" (Reed, 2001) in mind, the participating journalists said they made sure to keep their writing easy to understand and avoided going in to technicalities. It is also interesting to note that two of the four journalists (FSJ3 and FSJ4) included themselves and their own interests in their definitions of the audience.

Perceived role of science journalism

When asked about how they currently viewed their role as science journalists, as well as the role of science journalism as a whole, all four participants indicated they saw their responsibility as science journalists as first being to get audiences interested in science. One journalist pushed this thought a bit further, saying the role of science journalism is to get people "excited" about science (FSJ3). Other then raising interest, one participant said she believed the role of the science journalist is to raise the audiences' science literacy (FSJ1), while another said it was to inform people with a goal of providing them the tools to act responsibly as citizens and participate in democracy (FSJ4).

Findings related to test-story production

Overview of story assignment and use of the provided guidelines

Data from these three themes was organized and compared with the four model-based guidelines in order to determine which models approximated the journalists' everyday practices, as well as which models their everyday practices were least comparable to. This analysis, as well as the assignment of the models, is summarized in Table 3. All four journalists seemed to generally make use of traditional model elements in their daily work. Two journalists fell into the science literacy category, while two fell into the contextual category. Thus, the four journalists were assigned one traditional model most similar to how they already worked, and one non-traditional model different from how they usually worked. This was done in order to give the journalists one model they would be familiar with (possibly without realizing it) and be able to navigate relatively easily, and one model that they would not be familiar with from their usual work.

The journalists were asked to write about a Concordia University research project on genomics and biofuels (see Appendix I) and in doing so tended to write about the science itself, interview the researchers and other expert sources, and conclude with the implications and future promise this research holds for energy issues. It was clear that the guidelines for the science literacy and contextual models were used in the most comprehensive fashion, but that journalists had difficulty with applying the guidelines for the lay-expertise and public participation models. It was also clear that journalists turned to experts as their main sources and generally treated science positively in writing about how the research project covered could provide potential solutions to energy issues.

Table 3: Participating journalists' usual models

	FSJ1	FSJ2	FSJ3	FSJ4
Purpose	expanding knowledge	communicating and promoting science, making science accessible to all	communicating and promoting science	informing, give audience tools
Focus	story-selection driven by PR, other media, social media	story-selection driven by PR, focus on real-world application of science	story-selection driven by PR, focus on "wow-factor" of science	focus on experiences, characters in the story
Style	classic information delivery	classic information delivery	classic information delivery	mostly classic information delivery, although non-traditional at times
Sourcing	experts, non-experts to give context	Experts	Experts	experts and non-experts
Audience	low science literacy, interests drive story	low science literacy, interests drive story	low science literacy, interests drive story	low science literacy, interests drive story
Science	science and non-expert opinion needs balance	expert knowledge is valued over others	expert knowledge is valued over others	non-expert knowledge valued, but scientific knowledge comes first
Most similar to	contextual	science literacy	science literacy	contextual
Least similar to	public participation	public participation	lay-expertise	lay-expertise

Additionally, journalists tended to treat audiences as spectators outside of the story and, in all but one case, wrote their stories according to traditional journalistic style that aims at "translating" scientific information into understandable news stories and information delivery from experts to audiences (Brossard & Lewenstein, 2010). Below, each type of story as per the four models (Appendices II-V) is examined in more detail.

Analysis of the science literacy stories (Appendix II)

The two science literacy articles focused on the research project journalists were asked to cover and aimed at informing readers about the science involved. In doing so, the stories followed a traditional information-delivery style, treating readers as spectators and using scientific experts as the only sources of information. These articles positioned science as the only form of legitimate knowledge and wrote about the positive implications the science could have on energy issues. Thus, the two science literacy stories followed the story-writing guidelines provided (Box 1).

The science literacy story written by FSJ2 entitled "Applying high tech methods to the study of lowly fungi" (Appendix II), for example, placed the emphasis on the scientific and technical aspects of the project, and had as its goal to inform and educate audiences about the science, which corresponded to the purpose guideline for the science literacy model. Similarly, the story also coincided with the implied focus criteria, as it concentrated on the science behind the research project and justified its newsworthiness through the science's 'wow' factor. The journalist did this specifically by casting a particular fungus as a main character in the story to show what its larger scientific role was:

> Nevertheless, Concordia University's Justin Powlowski has cast *A. niger* as a star participant in an ambitious exploration of the unique biochemical capabilities of fungi. The project, Genozymes for Bioproducts and Bioprocesses Development, features this particular fungus in the study of how genes function in dozens of different fungi. (science literacy story, FSJ2)

This test-story also followed the science literacy style, sourcing and audience guidelines by writing the story in a classic journalistic style aimed at transmitting information from experts (i.e. the scientists and researchers directly associated with the project covered) who were used as the main sources, while the readers were positioned as a passive audience meant to be informed about the science through the story. The journalist also did not question the scientific knowledge in this story – as the science guideline for the science literacy model indicated – and presented the work done by the experts in a positive light and as providing potential solutions:

> Some of those processes could have significant industrial implications, according to Concordia biologist Adrian Tsang, who is heading up the project. He points out that fungi marshal a wide array of enzymes to decompose everything from organic waste on the forest floor to plastic deposited in municipal landfills. However, few of these complex chemical interactions have ever been formally analyzed. (science literacy story, FSJ2)

The science literacy test-story written by FSJ3, entitled "Ethanol: Fermenting Change" (Appendix II), also followed the story-writing guidelines closely as FSJ2's science literacy story did, however with a few differences. FSJ3's science literacy story seemed to be written with the purpose of informing readers about the research project itself, by communicating the science behind the project to non-scientists. As FSJ2's science literacy story did, FSJ3's story also focused on the novelty of the science itself:

> Imagine making beer out of wood chips, and you'll have some idea of the challenges facing researchers at Montreal's Concordia University.
> It's not that the team of biologists and chemists is looking to develop some kind of ultimate I-am-Canadian brew; their goal is to extract ethanol from forestry and agricultural waste. (science literacy story, FSJ3)

While the style and sourcing in FSJ3's science literacy story largely followed the criteria given, there were some discrepancies. For example, while the journalist did use experts as the main sources, they were only paraphrased and not directly quoted in the story. Despite the absence of direct quotes, the story did follow a classic information-delivery style in seeking to transmit scientific information to audiences. The audience and science criteria were also applied: the language used indicated that the intended audience members were non-scientists who were treated as spectators to be informed by the story without having any direct involvement in the story, while the scientific information written about in the story was legitimized by the fact it came from experts (i.e. the scientists involved with the project), and viewed as able to provide solutions:

> Beer from wood chips? Not so much. But at Concordia University, just the idea of fermenting plant waste is giving researchers a buzz – about a better future. (science literacy story, FSJ3)

Analysis of the contextual stories (Appendix III)

While the contextual model stories did follow the style, sourcing, audience and science guidelines -- in that they were written according to a traditional information-delivery style that aimed at informing passive audiences about the science and mainly interviewing scientific experts, treating them as the main sources of legitimate knowledge with non-experts used only as secondary sources to provide background – the purpose and focus criteria were more difficult to discern in the articles (Box 2). The guidelines asked journalists to write their stories with a goal of putting the science into context for the audiences by focusing on how it related to them. The guidelines thus implied the stories were to be tied to particular contexts; however in reading these articles, it was difficult to detect exactly what audiences they were aimed at.

For example, the contextual article written by FSJ1 (Appendix III) aimed at informing the audience about the research project and the science behind it, but did not include elements to identify what context the story was tied to outside of the science itself, or what particular audiences it was targeted to. Although the article did focus on the "food for fuel" debate in the United States, it did not explain how such a debate, nor the research done by the scientist interviewed, might impact a particular community or individual, nor did it use non-expert or community sources to provide background on how these issues relate to them:

> Food for fuel hasn't quite hit the public radar in Canada, but it exploded in the United States four years ago after then-president George W. Bush said his country should generate 132 billion litres of biofuels in a decade to wean 15 per cent of American fuel usage off of gasoline.
>
> With the United States' 430 million acres of cropland already heavily farmed, pointed out *Business Week*, it would be difficult to find the additional minimum of 50 million acres needed to fulfill Bush's wish. (contextual story, FSJ1)

The style guideline in this story was accurately represented in a classic journalistic style focused on information-delivery from experts to audiences, with scientists used as the main sources. The science criterion was also present as, the journalist focused on the positive aspects of the science and positioned it as able to provide answers. However, community members, community leaders, organizations, and other non-expert sources were not present in the article to provide background or context, as the guidelines suggested. While the article was aimed at informing an audience of non-experts, it was unclear whether the journalist had a more specific audience context in mind. For example, scientists are quoted as saying the public may not be supportive of the research project, but there is no further evidence in the article of community or non-expert sources providing the background to such concerns:

> “My fear is the public not having faith in what we do or what we say, and then we lose out,” said Adrian Tsang, a group researcher and the director of Concordia's center for functional and structural genomics. At Concordia, the researchers said they try to make that decision easier through lectures and demonstrations on the research...Since Concordia researchers predict it will take at least a decade to get their research used in industry, keeping the public continually informed about this is one of the project's greatest challenges. (contextual story, FSJ1)

Although the article references “the public,” it is the scientist-sources providing this information and background, and not “public” or community voices as the guidelines suggest.

The second contextual model-based story written by FSJ4 and titled “Fungi to Fuel our Future: Canadian Scientists” (Appendix III) followed the purpose, focus and style criteria, as it was a classic journalistic style story aimed at specifically informing Canadian readers about the scientific aspects of energy issues and how they affect them, as framed by the Canadian government’s five per cent biofuels mandate and the food for fuel debate:

> At present, the ethanol added to gasoline in Canada is produced from corn and grains. New federal laws require that all gasoline sold in Canada contain at least five percent ethanol.
>
> “There’s a lot of opposition to using food crops for producing fuel so that someone can drive their car,” says Concordia biofuels researcher Justin Powlowski, “What we’re interested in are residues of things that are harvested anyway,” including straw and forestry wastes, from branches to leaves. (contextual story, FSJ4).

The above excerpt also indicates how science was positioned throughout the story as able to provide solutions to a particular dilemma (i.e. opposition to using food crops for fuel), which coincided with the guidelines. The audience guideline was also represented, in that the story was aimed particularly at a Canadian audience. However, while readers were treated as passive spectators, as with the contextual story written by

FSJ1, this story also seemed to ignore part of the sourcing guideline. The story used three main scientific and technical sources and included only the voices of experts. Community members, community leaders, and other non-expert sources were not directly present in the article (Box 2), and thus there was no indication these types of sources were used in providing background/context.

Analysis of lay-expertise stories (Appendix IV)

The journalists applied the guidelines for the lay-expertise model (Box 3) completely differently between the two stories. While one made use of all six criteria, writing a story aimed at legitimizing knowledge outside of science, empowering lay-people, and following a non-traditional style, the second story displayed more elements from the contextual model guidelines (Box 2).

For example, the lay-expertise story written by FSJ3, entitled "Science, Hearts and Minds" (Appendix IV), directly implicated a community with the science and ongoing research by seeking and reporting on their opinions and past experiences. Thus, it focused on the attitudes and knowledge held by community members:

> A team of researchers at Montreal's Concordia University, I told him, was developing an economical method to convert forest waste into ethanol, that much-sought-after replacement, or at least supplement, for gasoline. The goal was to find a natural agent that would get ethanol out of wood and plant waste in much the same way – and as easily – as yeast gets beer out of hops. Commercial application was only a few years away.
>
> I didn't bother pointing out that Bancroft, with its saw mills, was a contender for the world capital of forest waste. Bob didn't need me to connect the dots. I simply waited for some expression of cautious excitement.
>
> What I got was a long silence and something that sounded like a sigh.
>
> "We've been here a lot of times with a lot of projects," he finally said. "Raising the community's hopes really isn't good." He ticked off a list of proposals and schemes that had seemed like sure things – and then just faded away. "We've

> heard dreams before. But people need to do their homework, develop a really solid business plan." (lay-expertise story, FSJ3)

As was shown in the above excerpt, the story was written from the journalist's point of view, with the journalist taking on a sort or narrator role and also acting as a source himself, style features not often seen in traditional journalism. Correspondingly, the other sources in the story were mainly community members treated as local experts, while the scientists and science were present only to provide background and context. The story was also aimed at the community referenced in the article, however the story may also be of interest to a wider audience in the sense that it showed what kinds of issues and opinions "real people" have in connection with the science and the research project. Finally, this story positioned science as one form of knowledge among many. It was treated as uncertain, while local knowledge was valued, which coincides with the criteria and guidelines for the lay-expertise model.

The second lay-expertise article written by FSJ4 and entitled "Green or Red Light for Ethanol?" (Appendix IV) did not incorporate all six story-writing criteria. Although it did use sources from outside of science in the story, the article largely stayed within a traditional journalistic style seeking to deliver expert scientific information to lay-audiences:

> "It's not a good idea to rely on ethanol," says John Caldwell, filling his van at a Francis Fuels station in the Ottawa Valley town of Almonte, a half-hour drive from Parliament Hill. "We have people starving in the world who can't afford to feed themselves so that we can drive gas guzzling cars." (...) It's this so-called second-generation biofuel approach that has some Montreal-based researchers arguing there's a made-in-Canada solution to the ethanol food versus fuel controversy.
>
> The Concordia University researchers are searching for new fungal enzymes – the same kind that turn compost scraps into soil -- than can help turn forest and field wastes, such as branches and straw, into ethanol. The enzymes are used to digest

> these tough woody fibres and turn them into simple sugars that can be fermented to make ethanol.
>
> "(Researchers) knew before that there were problems with corn-based ethanol," but there were strong political and economic interests in the US pushing this route, says Concordia biofuels scientist Adrian Tsang. He says the future of new biofuels can learn from this. (lay-expertise story, FSJ4)

While the article did focus on a specific dilemma faced by what could be considered the Canadian community, it did not necessarily show any evidence of focussing on local knowledge or community-based solutions, nor did it seem to have empowering community or promoting engagement with science as its purpose. As for the audience, the story was aimed at readers with little science background, specifically Canadian readers who may be affected by the research in question; however it was unclear whether audience input was sought after in the form of knowledge and viewpoints beyond the opinion of the one non-expert quoted at the beginning of the article. Instead, this story showed attributes associated more with the contextual model criteria, in that it informed a Canadian audience about scientific research and information as it related to Canadians.

Although the legitimizing factor in this story was the scientific information coming from the experts themselves, it was interestingly treated as uncertain in that this notion was underscored by quotes from the scientists themselves:

> "It's not all advantages," Tsang notes. For example, agricultural and forestry wastes could only ever supply a small fraction of biofuel needs, thus creating demand for "energy crops" such as trees and crops from non-agricultural lands. (lay-expertise story, FSJ4)

Analysis of public participation stories (Appendix V)

The public participation story-writing guidelines were the most difficult for journalists to follow. For example, in the public participation story written by FSJ1 (Appendix V), references made to audience participation and making responsible choices did suggest the article's purpose was to promote active engagement in the issues (Box 4, purpose guideline). However, the article did not focus on how the audience can become more actively engaged with the scientific process, nor did it focus on other voices beyond the scientific experts, as shown in the following excerpt:

> At Concordia University, researchers are inviting the public in to public lectures to learn how they are breaking down the genomes, or genetic makeup, of about 30 different types of fungi to see what enzymes could be suitable for fuels.
>
> Running your car or furnace takes a chemical "spark" to get the reaction going, and enzymes are the proteins that drive the spark. Researchers at Concordia are working to find the best chemical combinations possible for the fuels (public participation story, FSJ1).

Although the journalist did go beyond the scientists associated directly with the project in question, the viewpoints and opinions expressed in the story were limited to experts, with no community sources included and the story presented in a classic information delivery style, with science and the experts informing non-experts in a top-down fashion. Similarly, the journalist seemed to envision the audience as specifically Canadian in the story-writing process, but did not include their input in the story. Although the article highlighted the importance of active citizen engagement by referencing public lectures given by the scientists, and suggested society has an important role in ensuring science is carried out responsibly and to take possible consequences into consideration when making decisions, science was still positioned as the legitimizing source of information and was treated as able to provide answers to the issues addressed.

Similarly, the second public participation story written by FSJ2, "Back to the future: searching for genetic needles in a haystack" (Appendix V), limited its purpose to informing readers about the science and the solutions the experts are working towards, and not promoting active engagement as the guidelines suggested:

> Tsang, for his part, acknowledges the complexity of the task, but remains optimistic about the ultimate objective. He points to the discovery that animals like cattle emit large amounts of methane because their digestive tracts lack specific enzymes to digest grain. If the action of these missing enzymes can be identified, they can then be added to cattle feed and the output of this potent greenhouse can be reduced.
>
> "Quite clearly, we are transitioning to a biomass-based economy," he concludes. "This is how we will reduce our energy requirement, as well as our environmental footprint." (Public participation story, FSJ2)

The story's focus was on the science itself and did reference some of the behind-the-scenes components, such as funding mechanisms, but did not take into consideration the long-term effects or consequences the choices made may have. The journalist tended to position science as fixed and certain, and thus able to provide solutions without tying it back to social aspects, as the guidelines suggested (Box 4):

> Tsang, a Concordia University biologist, sees this future emerging from the humble yet crucial activities of the world's fungi. These simple creatures mediate complex arrays of biochemical interactions, displaying an unrivalled ability to digest substances as unlikely as plastics or kerosene.
>
> "These organisms are the major decomposers of terrestrial biomass," he says, noting that we have harnessed this capability to make fermented commodities like bread or alcohol. We can even turn crops such as corn into viable fuels, although replacing all petroleum use in this way would undoubtedly compromise our ability to feed ourselves. (public participation story, FSJ2)

This story was written in a classic journalistic style aimed at top-down information delivery from experts to audience, instead of a more "communal" style that sought to map the opinions and viewpoints of stakeholders (Box 4, style guideline). The story's sources were limited to scientific experts, and did not include stakeholders from outside of science. The audience was not implicated in the story and instead was treated as passive spectators, similar to the criteria of the traditional science literacy and contextual models.

Discussion

Following the analysis of the eight test-stories, the science literacy model criteria were the ones most closely adhered to by the participating journalists in the story-writing process. As the science literacy model is a dominant form of communication seen in science journalism that seeks to promote science literacy by transmitting expert knowledge to audiences perceived as having low or basic science literacy (Brossard & Lewenstein, 2010; Gerhard & Schäfer, 2009; Logan, 2001), this is not surprising, especially given that the pre-interviews revealed it was most similar to the practices and routines of the participating journalists assigned this model. This comfort lead to the journalists placing focus on the science itself and following a traditional information-delivery style that treated readers as spectators and used scientific experts as the main sources of information when writing their test stories.

As for the remaining three models (Figure 1), the six criteria were not fully represented across all stories. For example, the traditional stories -- science literacy and contextual (Appendices II and III) -- adhered to the style guidelines, using classic information delivery style to transmit expert information and scientific knowledge to audiences. However, out of the four non-traditional stories, only one stepped outside of the traditional journalistic style as the guidelines suggested. The lay-expertise story in question (Appendix IV, FSJ3) used a style uncommon in traditional journalism and took on a first-person narrative style, with the journalist himself almost acting as a source throughout the story. Interestingly, this lay-expertise story was also to be the only non-traditional test story that followed all six story-writing criteria (Box 3). This may suggest that non-traditional story style is connected to the other five story-writing criteria; however this assumption requires further investigation through interviews with the journalists (Chapter 3).

The sourcing guideline was not fully reflected in the contextual stories (Appendix III), the public participation stories (Appendix V), as well as one lay-expertise story (Appendix IV, story by FSJ4). Although the journalists were asked to go to community and non-scientific sources during the story-writing process, there is no evidence in the articles that this was done. Instead, they relied mainly on expert voices, similar to what the science literacy model-based guidelines prescribed. The literature has indicated that science journalists rely mainly on expert sources to provide information, quotes, context and legitimacy for their stories (e.g. Nelkin, 1995; Hinnant & Len-Rios, 2009; Ward & Jandciu, 2008; Chew et al., 2006; Geller et al., 2005; Waddell et al., 2005; Conrad, 1999). The participating journalists may have fallen back on such usual practices in writing stories that asked them to do otherwise, and may have also been hampered by such obstacles as time and space (e.g. Ward & Jandcui, 2008; Larsson et al., 2003; Saari et al., 1998) in finding sources from outside of science to include in their stories.

The audience guideline in the non-traditional model stories, specifically one lay-expertise story (Appendix IV, FSJ4) and the two public participation stories (Appendix V), was not followed, with audience opinion and concern not obviously present in the articles. Instead, these journalists tended to treated their audiences as passive spectators, which was evidenced by the fact that these stories applied top-down information delivery styles similar to the science literacy and contextual model guidelines, and did not include voices from the audience in the stories in order to demonstrate active engagement or treat them as stakeholders in the scientific process (Boxes 3 and 4). Furthermore, the stories indicated the journalists defined their readers broadly instead of targeting their stories to particular audiences, especially in the contextual stories (Appendix III), public participation stories (Appendix V) and one lay-expertise story (Appendix IV). This may be related to the identified lack of understanding science journalists have about their audiences and how they make use of science journalism to gain knowledge (Treise & Weigold, 2002). The science guidelines were applied inconsistently in one lay-expertise story (Appendix IV, FSJ4) and the public participation stories (Appendix V), as science was largely presented as the legitimizing form of knowledge and positioned as able to offer solutions.

These results suggest the journalists maintained practices similar to elements of the science literacy model – thus suggesting the contextual, lay-expertise- and public participation-based sourcing, audience and science guidelines were different from their usual routines. However, the pre-interviews indicated that at least two of the journalists (FSJ1 and FSJ4) did in fact normally hold several routines and practices similar to the contextual model sourcing guidelines, implying that they would be familiar with practices that involve using sources from outside of experts and scientists at least to develop context and background in their stories. This discrepancy needs further exploration in the journalist interview phase discussed in the next chapter.

The purpose and focus criteria seemed to be connected across the eight test stories, possibly implying that story purpose drove the focus. The contextual and public participation stories, as well as one lay-expertise story, did not seem to have clearly defined contexts or intended audiences that were focused on, and were written with a purpose of informing audiences about the science, although the guidelines suggested otherwise (Boxes 2, 3 and 4). These discrepancies with the criteria require further investigation through journalist interviews.

The above identified trends in the test-stories imply that the science literacy guidelines were adhered to most, while the guidelines for the contextual, lay-expertise and public participation stories were applied less consistently. This was to be expected, as the science literacy model that seeks to transmit expert knowledge to audiences is a dominant model of communication in science journalism (Brossard & Lewenstein, 2010; Gerhard & Schäfer, 2009; Logan, 2001). Two of the participating journalists also reflected this in the pre-interviews by indicating that their usual routines and practices approximated the science literacy model. However, these observations alone are not enough to draw solid conclusions on how the criteria and test-story production are connected, and thus require further investigation through interviews with the journalists that focus on their own explanations of how they interpreted and used the story-writing guidelines in developing the test stories.

CHAPTER 3 – Insider information: Exploring the interpretations and applications of science story criteria through interviews with freelance science journalists

As Treise and Weigold (2002) articulated, there are some research questions that require investigating the "emic view" (p. 316) —a viewpoint that a cultural insider would accept as appropriate and meaningful. Thus, in order to gain a deeper understanding of how the freelance science journalists participating in this project – the "cultural insiders" in this case – interpreted the science communication model-based guidelines previously discussed in Chapter 1, as well as to deepen and verify the analysis of the eight test stories described in Chapter 2, in-depth, semi-structured qualitative interviews were carried out with each of the four participants.

This chapter begins with an overview of the themes that emerged out of the interviews and describes the extent to which the journalists made use of and applied the story-writing criteria they were provided (see Chapter 2) or relied on their usual routines and practices. Specific attention is given to how story-writing criteria application differed between traditional model (science literacy and contextual) and non-traditional model (lay-expertise and public participation) stories based on the journalists' descriptions. This chapter concludes with a discussion on how the journalists' descriptions of their interpretations and application of model-based guidelines relates to the most effective operationalization of theoretical models of science communication in science journalism practice.

Method

The importance of investigating the "experiences of life from the perspective of the insider—the person who is having the experience" (Paterson et al. 2001, p. 3) is what led to the choice of using interviews in this research. Such a qualitative approach has been noted to help uncover journalists' tacit knowledge or the "unexpressed, but closely adhered to, ideas of how to do their work" (Hinnant & Len-Rios, 2009, p. 85). Qualitative interviewing was considered a necessary tool for this project to investigate the lived experiences of the participating journalists in producing the test stories and avoid misinterpretations and misunderstandings that may have occurred in the initial analysis of how the story-writing guidelines were understood and applied in the test stories described in the previous chapter. Qualitative interviews also play an important role in the social production of knowledge, in which the interviewer and interviewees co-construct knowledge through conversation (Kvale & Brinkman, 2009). Thus, qualitative interviews were viewed as the most efficient research tool to add nuance to the understanding of how participating journalists made judgements related to the use the previously articulated guidelines (see Chapters 1 and 2) during the story-writing process and to help gain first-person narratives on the complex relationships between the journalists and the stories they covered for this project.

It should be noted that the researcher had a background in journalism, and thus was essentially a journalist interviewing other journalists. Such relationships can cause problems, specifically misinterpretations of what is being said, since interviewer and interviewee share a common background and language, and may take statements and their implied meanings for granted. As Plesner (2011) suggested, such issues can be overcome by adopting the approach of "studying sideways." She wrote: "...I argue that the problem is not one of unequal relationships, preconstituted interests, or the steering of interviewees but one of language use. If this is the case, an interview strategy could be to explore the limits of commonality, by constantly pushing interpretations so far that they no longer seem agreeable to interviewees. Also, we could expect to get to know the practices they tell us about better through their defence against the interviewer's misinterpretations" (p. 478). Thus, in the interviews with the participating journalists, their explanations and statements were not taken for granted. They were instead asked to reflect on their statements and their meanings were questioned in order to avoid misinterpretations of what was said on the part of the researcher.

Four individual interviews were conducted over the phone on March 21-22, 2011. Interviews lasted between 45-90 minutes, and were audio-recorded. Each interview recording was fully transcribed, and then the data were organized according to the four models of science communication covered in this research in order to effectively investigate how the six criteria were applied in each of the model-based science journalism stories.

An interview guide outlining topics to be covered (Kvale & Brinkman, 2009, p. 130) was developed in order to structure the four individual interviews in a way that would allow comparison between them. A semi-structured design with open-ended interview questions was chosen over a fully-structured script, as some research suggests that an unstructured approach may in fact lead to the data-densest interviews (Corbin & Morse, 2003, cited in Corbin & Strauss, 2008, p. 27).

As the purpose of the interviews was to elicit how the journalists explained, in their own words, their approaches to applying the story-writing guidelines, the interview guide included five topics:

1. Each journalist was asked to describe their overall impressions on the story-writing process and their reactions to using the model-based guidelines.
2. The interview next focused specifically on the story-writing guidelines (Chapter 1) and asked journalists to describe their interpretations of them and how they applied them in their two stories.
3. Thirdly, the journalists were asked to reflect on the story-writing process and, in retrospect, speak about anything they would have approached differently if they were to start the process from the beginning.
4. Fourth, the journalists were asked to speculate on whether the option of using other forms of media – such as audio, visuals, or multimedia -- would have changed their approach to applying the guidelines in their stories.
5. Finally, the journalists were asked to re-describe what they thought was their own model of science journalism. This question, as compared with the pre-interviews (Chapter 2), served as a way to judge whether the journalists made use of the criteria in the story-writing process or relied instead on their already-established routines and practices.

The analysis of the interviews followed a grounded theory approach, in which the data were broken apart and coded according to distinct concepts (Corbin & Strauss, 2008; Creswell, 2007). The qualitative software Nvivo 8 was used to help in the coding process. The concepts were reorganized and connected back to the model-based story-writing guidelines in order to articulate the relationships between them and examine the potential meanings and consequences of the use of the six story writing criteria (Corbin & Strauss, 2008; Creswell, 2007).While the data was allowed to guide the coding process to a certain extent, the original interview guide and questions helped to structure the analysis and avoid interpretations solely based on the researcher's intuition (Corbin & Strauss, 2008, p. 198).

Findings related to story-writing criteria

Purpose

When speaking about the purpose criteria for the science literacy story-writing guidelines (Box 1), one journalist articulated his approach to the story's purpose as translating the science in a way audience members could understand:

> I wanted to communicate sort of the -- what the basic idea was, what was involved in the science. (FSJ3)

That same journalist saw the purpose of the story as informing the audience about the science and the project. This was combined with another expressed purpose of a science literacy story as creating "access points for science literacy" through "good" science journalism writing, which was described as interesting and entertaining (FSJ2).

While the above three concepts – translation, information and science literacy – fall in line with the story-writing guidelines given to the journalists, there was one concept brought up in the interviews on the science literacy story-writing process that was not articulated in the guidelines, namely engagement. This concept was brought up by FSJ2 (Table 2), the same journalist who cited science literacy when speaking about the story's purpose. He connected this purpose to engaging audience members with science by getting people interested, thinking about, and talking about science, specifically through interesting and engaging writing. This journalist's use of the word "engagement," however, implied a purpose of getting people interested in the science itself, rather than promoting active engagement, such as in the lay-expertise and public participation model guidelines:

> We all need to be engaged directly...So then you say, what is this fungus? What does it do? And I could have gotten a very disappointing answer. You know, this was some strange fungus found on an island in Indonesia. I can't relate to it, I have no information and it just isn't interesting. But instead, this is the same bloody fungus that turns my vegetables on the counter black. And suddenly I have a way in. It's the same thing. And they are studying it. And this is where the science writing gets good. (FSJ2)

When asked to speak about the purpose of contextual stories, there were slight distinctions between the ways the journalists articulated how they applied this guideline. While one said the purpose of the article was to show how the science in the story related to the audience's personal lives or experiences (FSJ1), the other journalist said the purpose was rather to show the audience how the particular science research project discussed in the story related to the larger picture:

> This is a broad international phenomenon that they're part of and that they're hacking away at a particular piece of it. So, that allows me then to talk to them with a sense that, okay, this is where it fits into a bigger story. (FSJ4)

FSJ4 also cited explaining where the particular research project fit into the bigger picture as the guiding concept behind the purpose of his lay-expertise article. Both journalists working with the lay-expertise model guidelines also referred to empowering local communities as the purpose of the story. One journalist explained this as directly tying the science covered in the story to a particular community (FSJ3), while the other said the purpose of empowering audiences was achieved through showing readers that the choices made regarding biofuels carry consequences and need to be carefully considered:

> But do we want to be using ethanol, and especially food-based ethanol and maybe even second-generation biofuels? So that was the approach I was taking. (FSJ4)

It is interesting to note, however, that both journalists who had used the lay-expertise model guidelines had difficulty speaking about the purpose criterion without referencing the focus of their stories, a concept that will subsequently be discussed in more detail.

Finally, as for the journalists using the public participation model guidelines, the two concepts referenced were also those brought up when speaking about the science literacy model. One of the journalists said the main purpose of the story was again to inform audiences about the science and the research project (FSJ2); however the larger goal, referenced by both journalists, was engagement. One journalist admitted actually putting this into practice was difficult – as it was completely different from her usual routines and practices – but attempted to implicate audiences by keeping “the audience’s actions in mind” (FSJ1) throughout the writing process, and referencing public engagement events taking place, such as talks and lectures organized by the researchers associated with the research project covered in the article:

> Here they might go, oh, I want to go in to the university and actually talk to these researchers and do some more research for myself on the story, from a citizens’ point of view. (FSJ1)

The second journalist viewed “engagement” differently, articulating this concept as getting readers engaged with the science by showing them how they can relate to it, specifically by focussing on the scientist as an everyday person, and their work as something anyone could potentially do. In other words, this journalist understood "engagement" as happening by personalizing the science through good writing and good story-telling:

> Any chance I have to tell people, well, how would you do it? Can you think of a better way to do it? You know, he did something really common sense...I suspect there were many, many Friday night beer sessions where they fought over this. And these guys will tell you those stories. But, to me, that engages an audience. It makes people human. (FSJ2)

Focus

It is interesting to note that the four participating journalists all either had difficulty expressing the focus of their two stories without referring to the purpose criteria, or spoke about them as one in the same, articulating that a story's focus could not be defined without a purpose, and vice versa. This concept spread across the journalists' descriptions of all eight test stories. As one journalist expressed when speaking specifically about the science literacy model guidelines (Box 1):

> For science literacy, I think the purpose was really clear. Like I said, I had a bit of trouble with the focus guideline and knowing exactly what that meant. (FSJ3)

Generally, the journalists explained that once they had articulated what their story's purpose was, this guided how they chose their focus and drove what they wrote about. This was illustrated by one journalist who articulated how the focus guideline was put into practice in her contextual-model story (Box 2) by explaining they were essentially the same:

> Well, it was sort of the same thing, because the purpose was to try and find something that the audience can relate to. And then you were trying to focus on an event or on a concern that was specific to a particular population. (FSJ1)

Another common way journalists expressed their application of the focus criteria was by using the same language found in the story-writing guidelines they were given, such as "wow factor", "conflict," "community," and "dilemma". When pressed to describe the application of these criteria beyond the language in the guidelines provided to them, the journalists often did not, or expressed difficulty in doing so. This may imply once again that the purpose and focus were considered as complementary criteria or one in the same, or that the focus criterion was largely taken for granted once the journalists had already defined the story purpose.

An additional concept raised by two of the journalists when speaking about the focus guideline was specifically the economic and financial aspects of their stories. This was a concept not referred to directly in the purpose criteria, or in the focus guidelines, but was something two of the journalists brought up independently, specifically for the contextual and public participation model stories. However, the focus on money in these stories may still relate back to the purpose guideline. For example, one journalist, who cited relating the science to the audience's lives or experiences as the purpose of her contextual story spoke about the focus of the same story in terms of how a Canadian business is spending money on Canadian research and development into biofuels (FSJ1). The other journalist, who cited getting the audience engaged with science as a purpose of the public participation story, said money was used as a focus in the story to draw the audience in and get them to connect with what the science might mean to them:

> I find that the money is often a way of even getting lay-people engaged. Where they say: "Well why is that much money going into this thing where they're looking at mushrooms?" And you say, well, here's why. And this is what engages people. (FSJ2)

Style

Not surprisingly, journalists expressed the styles of their stories either in traditional journalistic terms when speaking about the traditional model stories (science literacy and contextual), and in terms not generally common in journalism when speaking about the non-traditional model stories (lay-expertise and public participation). For example, journalists working with the science literacy and contextual model guidelines said they wrote their stories according to a classic journalism style aimed at transmitting information about the science to audiences:

> You know, the sort of inverse pyramid. Give them a little bit, and then give them a little bit more, so that you can trim the end at any point. (FSJ3)

> I think in terms of that traditional information driven style, I'm essentially delivering the – in some ways it's like writing from a press release, you know, in the sense that this is essentially telling their story. Because this is a relatively technical story that needs to be broken down and digested into its kind of core nugget. So, I would say generally sort of a science popularising style. (FSJ4)

One journalist specifically pointed out special attention was paid to the language used in order to ensure it wasn't overly scientific or technical for a general audience (FSJ1). Another journalist went even further, expressing the opinion that such a classic journalism writing style was in fact the most effective approach to most science journalism:

> And with a pure science literacy story like this, I don't see any other way to go. To play around with it and try to be cute with it just doesn't work. People have legitimate questions: who's paying for this, how much did they get, what exactly are you planning to do with this? To me, that was the function in terms of pure literacy. (FSJ2)

When it comes to the non-traditional model stories, the journalists largely articulated the styles used in such terms as "active engagement," "issue focused," "story-line focused" and "non-linear." While such statements may give the impression the participating journalists did follow the story-writing guidelines, the analysis of the test stories indicated otherwise (Chapter 2). Although the journalists said they used writing styles outside of traditional journalism information-delivery, three of the non-traditional model based-stories looked and read very much like classic journalism, with only one of the non-traditional model stories – specifically FSJ3's lay-expertise story (see Appendix IV) -- stepping outside of this style. This journalist articulated the story's style in more narrative terms, by explaining the aim was to have a "beginning, middle, and an end." FSJ3, who interestingly did not have any formal journalism training but had been working as a freelance science journalist for about 10 years, wrote this story from a first-person point of view and explained this choice by saying:

> I don't know. It just sort of happened. It just felt natural to me and I think it's because I feel like I'm a bit in the middle up here. I mean, I'm a relatively new resident -- which means I haven't been here for 80 years – by some of the local definitions. So, I think I felt naturally in the middle, so I just took that and decided to make it a first-person thing. And also, it was just a bit of an experiment. Not a lot of journalism – well, I guess more nowadays is done that way – but I thought it would be an interesting take on it. And I guess maybe it was a bit of a response to an "active engagement" thing that says, okay, I'm really "active engagement" in the first-person. (FSJ3)

By indicating he was a "relatively new resident" and "felt naturally in the middle," this explanation also points to the fact that this journalist was tied to the community and audience he was writing for and did not only view the "active-engagement" style guideline for lay-expertise model stories as applying solely to the audience, but also to the journalist.

Sourcing

The two main types of sources the journalists spoke about using in the stories, regardless of which models they were working with, were scientific experts and environmental experts.

For the traditional model-based stories, the journalists were asked to use expert and scientific knowledge as the primary source, which was reflected in the test-stories produced (Appendices II and III) and the journalists' explanations of how they applied the sourcing guidelines to them. However, although journalists were asked to prioritize other sources of knowledge in the non-traditional model-based stories, such as lay-expertise or "stakeholder" knowledge, only one of the four non-traditional model stories did so. Journalists largely explained this in the interviews by saying that, as these were science journalism stories, scientific sources needed to play a main role.

> Whatever the event was that prompted the story in the first place, it had been experienced directly by the people on the ground...With a science story, if there are actually people who have done the work, you want to talk to them. You don't want to talk to the guy who's managing the entire project and isn't in the lab any day or anything like that. (FSJ2)

However, although scientific experts still largely remained the main sources of knowledge and information in most of the non-traditional model-based stories, journalists explained that they made an attempt at presenting these experts differently than in traditional model stories: for example, instead of presenting them as scientists only, they were introduced to the readers as everyday people with a passion for science:

> I ask them explicitly for examples like this. You know, things that they find frustrating, or things that they don't know yet, or something that's stymied them. And this is – when you trot that out, this gets empathy from the reader for the problem. Then the reader has that sense of participation. And that's how I interpret "engagement." You know, the reader is sitting there going, I get this guy. (FSJ2)

While other journalists did step outside of science for their sources in the non-traditional model stories, they still seemed to have difficulty relying on lay-expertise or other forms of knowledge not provided by experts of some sort. This is most obvious in the use of environmental sources, which the journalists described as outside of science, but were still treated as experts:

> As opposed to the first story, this one I wanted to approach more environmental experts. Sorry, not experts; policy-makers. I wanted to approach more – it just was a matter of length and of time. It was one of those stories, especially with a

> big issue as this, where I felt like I could have used maybe three or four times the space. (FSJ1, public participation story)

The above quote also alludes to another common concept addressed in the interviews about the sourcing guidelines: the obstacles that hampered journalists from including sources outside of science or other non-experts in their stories, such as time/deadline pressures, geographic/location-based restrictions, and space limitations.

One journalist also mentioned traditional journalistic routines and practices may have kept her from stepping out of her comfort zone and going to sources she normally would not:

> That's something, as journalists, I think we're a bit too used to. Because often when we're searching for stories, we just go to the official sources and not so much the community aspect of it, unless you're part of a very specific type of news outlet. (FSJ1)

The one journalist who did privilege non-experts as the main sources in his non-traditional model-based story was the same journalist who chose to write from a first-person point of view based on the "active engagement" lay-expertise style guideline. When asked why the scientists and experts directly associated with the biofuels research project covered in the article weren't quoted directly, the journalist responded by saying: "That was my interpretation of the guidelines -- that the science really was in the background" (FSJ3). This journalist also mentioned that the style guideline for this story was approached as an "experiment" different from traditional journalistic styles, which may suggest that such a non-traditional approach may also drive sourcing decisions divergent from the expert-centred ones traditionally made by journalists (e.g. Nelkin, 1995; Hinnant & Len-Rios, 2009; Ward & Jandciu, 2008; Chew et al., 2006; Geller et al., 2005; Waddell et al., 2005; Conrad, 1999).

Audience

The journalists largely defined their target audiences very broadly, often expressing only a vague idea of who their readers might be. Terms that came up when the journalists explained their perceived audiences were: “everyday audience” (FSJ3), everyone, i.e. “we’re all the audience” (FSJ2), “general” and “Canadian” (FSJ4). Only one journalist (FSJ3) targeted his lay-expertise story to a very particular audience, specifically the community that the article in question was about. However, the same journalist also did mention that such a story might be of interest to a wider audience outside of that particular community.

The journalists generally described intended audience members as those with basic or low science literacy, sometimes reluctant to take the time to read about science topics or science journalism, but overall were still concerned or “curious” (FSJ2) about science when it came to traditional model-based stories, or concerned about the impact of science in their lives, when it came to non-traditional model stories:

> Yeah, I guess I see this as certainly for a general paper. I mean, this could also be for a concerned reader. I mean, someone who (cares) about what’s happening with these kinds of issues. (FSJ4)

While the participating journalists applied the audience as spectator guideline in the science literacy and contextual stories, a number of the journalists expressed difficulty or misunderstanding of how they interpreted having a more active audience and seeking audience input in the non-traditional model guidelines:

> I’m not sure that concept of audience member -- because, by its term, “the audience” are people who are outside of the story. (FSJ4)

Science

When speaking about the science literacy and contextual model stories, journalists generally said they followed the guidelines and positioned science as fixed and certain, presenting it as the main form of knowledge and without contending points or questioning its validity. However, a number of journalists said that, although they followed this guideline in the story-writing process, treating science as fixed and certain conflicted with their own views:

> I thought it was interesting that you said science should be viewed as fixed and certain, because it's really not in my view. But I just said, okay, I'll play along with it. So, I didn't question the science very much. I said, well, there's this debate going on in the States, but it's okay, the scientists are taking care of us. I guess that's sort of what I was thinking when I was writing it. (FSJ1)

With this in mind, while journalists did treat science as "fixed and certain," they did take steps not to over-hype the science, particularly in the contextual model-based stories, thus presenting science in a more moderate way. As the following journalist interview excerpt shows, this was often achieved by letting the scientist and expert voices temper their own excitement about the research covered in the article:

> I essentially treated it as you said, that the science is fixed and certain. There's more detail about what they're actually doing. That this is the number of genomes they've sequenced, this is the number that has been sequenced worldwide. I think then at the end, though, I add in – even though the science is fixed and certain -- having (the scientist) say that gene sequencing is only one thing -- he's buffering the enthusiasm for what he's saying. So he's balancing out his own perspective. But it's still coming from the scientist. (FSJ4)

As for the non-traditional lay-expertise and public participation stories, the journalists spoke about applying the science criteria as uncertain and embedded in society, much in the same language as the guidelines given to them:

> Yeah, so it's the tension between – the last guideline we talked about (in reference to the science literacy model-based story) was science is fixed and certain. And

> then, you know, (in the lay-expertise story) I've got some guys up here in flannel shirts and Caterpillar caps that are maybe not so certain that it's going to work. (FSJ3)

> I just analyzed the uncertainty a little bit more. Which I guess would fall into the end point more where it says science should be viewed as uncertain and embedded in society. Because, here it was talking about the process, and process, that word in particular, implies uncertainty. Because science is a process, it's not an end goal. (FSJ1)

Such statements reflect an effort on the journalists' side to present a more balanced image of science than in the traditional-model stories. However, when compared with the preliminary analysis of the test stories outlined in the previous chapter, it seemed that three of the four non-traditional model-based stories, despite including examples of how scientific information is not completely fixed and certain, continued to present it as the legitimizing form of knowledge, in that science was positioned as able to offer solutions to the energy issues reported on (Appendices IV and V). Only one of the non-traditional model-based stories (the lay-expertise article written by FSJ3) showed science may not necessarily be able to provide answers to community-based problems by focusing on community attitudes and lay-expertise as the legitimizing form of knowledge, which in this case demonstrated that community members were skeptical about what solutions the science might propose based on their past experiences. As only one of the four non-traditional model-based truly followed the science guidelines, this may indicate that experienced science journalists may be obstructed by already-established practices emphasizing focus on scientific experts and a tendency to present positive messages about science (e.g. e.g. Nelkin, 1995; Hinnant & Len-Rios, 2009; Ward & Jandciu, 2008; Chew et al., 2006; Geller et al., 2005; Waddell et al., 2005; Conrad, 1999) to do otherwise in the story-writing process.

Additional findings

When asked whether having the option of using different or additional forms of media for their stories would have changed the way they applied the story-writing criteria, all four journalists responded that it would not have changed their approaches to story-production. Consistent among the four journalists was also the reference to television as the main form of "other media" that could have been used to cover the science news story in question, with other forms of digital media or multimedia not addressed. The main impact the journalists envisioned the use of television having on their stories was the inclusion of visuals, however this was not seen as potentially having an effect on how the story-writing criteria would have been applied:

> It's just difficult with TV to find anything that's visual enough, especially with a story like this, because it would all be talking heads. (FSJ1)
>
> I don't think I would take a hugely different approach if it would just be visualized. (FSJ3)

While one journalist did speak of the possibilities of digital media, such as 3D animation, could have for science journalists, this was still not viewed as potentially having an impact on how the story criteria may have been applied:

> The underlying principles of storytelling and keeping the facts straight and having the characters – in fact, all of the six principles you have here – will not have changed. You will still need to have those in anything you lay out, whether you're using 3D holograms or avatars or who knows what else we'll have by then. (FSJ2)

Once again, the journalist spoke about applying the story-writing criteria in fairly traditional journalistic terms focused on information delivery and story-telling tools perceived to appeal to audiences, regardless of the media format used. Such statements may indicate the journalists find it difficult or are hesitant to view the story-production process, regardless of media format, beyond traditional journalistic norms and practices.

To conclude each of the interviews, journalists were asked to briefly speak about what they thought their usual model of science journalism outside of this research project was that they use in their daily work as freelance science journalists. Although spoken about in different terms, all four journalists articulated what they thought was their personal model largely in traditional journalistic terms:

> It's very source-driven…Really in my stories it's sources, and the information tying it together, because I find people are always the most interesting part of it. It doesn't matter if you're writing about business, or science, or municipal politics. People are what people relate to; not objects. And unfortunately, in the case of this story, not enzymes. (FSJ1)

> I tend to be very conservative and I'm more of a science literacy guy, almost the whole way, simply because most of us don't know enough about particular fields. And so I invariably start from that point. At the far end is the public participation model, which as I told you, I don't tend to venture into that neighbourhood very much. But I tend to always start at the literacy end of things, because I just feel that people articulate, oh, this is important, people need to know this, I want to know about it. The public has the right to know. (FSJ2)

> I think I'm maybe a little bit sort of halfway between these two sets of guidelines that you gave to me. And I've really – because I really try to be aware of the audience -- I think I'm thinking maybe more of them. And I think I'd like to do more of that, actually, kind of reflecting on this process. Sort of, what are the implications for you, my dear reader, you know? (FSJ3)

> I'm often writing about breaking science. So, science which is uncertain in the sense that it's sort of the bleeding edge of understanding, which is what science is...I'm often writing for science pages, where the emphasis is really on understanding the newness of the thing. (FSJ4)

The journalists' traditional everyday practices and routines evidenced here and in the pre-interviews (Chapter 2), focused on telling stories that engage audiences, transmitting scientific information to them, and mainly using expert sources to do so, and seem to have influenced how they interpreted and applied the story-writing guidelines in this project.

Discussion

Based on the journalists' descriptions, all four participants were of the opinion that their interpretations of the traditional and non-traditional model-based story-writing guidelines were accurate, and consequently considered their produced test-stories as representative of the models they were asked to work with.

However, as found in Chapter 2, the story-writing guidelines were not consistently applied between all stories, suggesting that the journalists often relied on their usual norms to make meaning of the model-based guidelines. When the journalist interviews are viewed against the analysis of their stories (Chapter 2), the test stories based on the science literacy model seemed to be the only ones that followed all six story-writing criteria described in the guidelines provided to the journalists. The two journalists assigned this model spoke of the story-writing process as similar to their usual practices. These usual practices involved writing science stories that seek to inform audiences about science by employing story-telling methods perceived to engage audiences, and using scientific experts as the main sources of information, all attributes of the science literacy story-writing criteria provided to them for this project (Brossard & Lewenstein, 2010; Box 1). However, for the contextual, lay-expertise and public participation models, the story-writing criteria were not as consistently applied, and often seemed to instead fall back on such traditional journalistic practices that at times diverged with and contradicted the model-based guidelines. For example, there were discrepancies between the contextual model sourcing guideline and its application: although scientists and experts were treated as the main sources and considered able to provide answers, questioning community and non-expert voices were not obviously present in the test-articles, and thus it was unclear what specific contexts the articles were written for. Journalists explained this discrepancy by saying obstacles, such as time, story length, and deadlines, hampered their efforts to include additional sources. Upon reflection, one journalist also pointed to the fact that it may have been traditional journalistic norms and practices themselves that caused this discrepancy with the criteria, as science journalism usually relies on experts as the main sources and providers of information for science journalism articles, rather than non-experts (e.g. Nelkin, 1995; Hinnant & Len-Rios, 2009; Ward & Jandciu, 2008; Chew et al., 2006; Geller et al., 2005; Waddell et al., 2005; Conrad, 1999).

It is interesting to note that when speaking about both the traditional and non-traditional model-based stories, journalists often discussed the purpose and focus criteria as interchangeable, which may imply that the focus criterion was largely taken for granted once the journalists had defined the story purpose.

The produced test-stories and journalists' descriptions of the story-writing process indicated that guidelines for the lay-expertise and public participation stories were interpreted and applied inconsistently. For example, although described otherwise, most journalists applied a traditional journalistic style to their non-traditional model-based stories, while only one journalist used a non-traditional style. FSJ3 wrote his lay-expertise story (see Appendix IV) from a first-person point of view, using narrative tools and style techniques not usually found in mainstream journalism (Nelkin, 1995; Mencher, 2003, pp. 177-182; Lublinski et al., 2008). The lack of non-traditional styles in these stories may be explained by the fact journalists, although they understood the guidelines, had difficulty envisioning how exactly to apply this in practice, as it is completely different from their usual routines and practices. Audience members were also largely treated as “passive spectators” by the journalists in the non-traditional model stories, except for FSJ3’s lay-expertise story, where members of the intended audience were directly included as the main sources and providers of information and knowledge. As for the science guideline, most of the journalists – except for FSJ3 in his lay-expertise story -- treated science as the main form of legitimate knowledge and showed reluctance in validating lay-expertise and other forms of knowledge outside of science.

Based on these trends, a central phenomenon was observed: traditional journalistic practices and routines focused on transmitting scientific information provided by expert sources to audiences through “good” story-writing were relatively fixed and hampered journalists from applying non-traditional model story-writing guidelines that emphasized styles outside of those focused on information delivery, sourcing practices that extend outside of the scientific and expert community, as well as treatment of the audience as directly implicated in the stories told. This implies that journalists tended to adhere to practices similar to those of the science literacy model (Chapter 1 and Box 1), although research has suggested such a model may be too narrow to deal with the complexities of modern science (Secko, 2009), has failed to make scientific information relevant to individuals and has ignored other forms of knowledge outside of science (Brossard & Lewenstein, 2010).

Such interpretations suggest that science journalists with formal journalism education backgrounds or extensive experience have their own sets of norms, routines and practices that they have difficulty stepping out of (Hodgetts et al., 2007; Roy et al., 2007; Waddell et al., 2005; Conrad, 1999; Hansen, 1994), often viewing that using such widespread journalism practices and routines is the best way to practice science journalism. This is supported by the fact that three of the journalists spoke of their practices almost as set rules, or the way things are "supposed" to be done, while the one journalist who did step out of traditional journalistic norms in his lay-expertise story (Appendix IV, FSJ3) had no formal journalism training and decided to treat the story-writing process in this project as an "experiment." This may further suggest that it is traditional journalistic norms and practices that are hampering the uptake of new forms and models of science journalism outside of the classic deficit and science literacy models to promote audience engagement with science, meaningful debate, and democratization of the scientific process. However, it remains unclear whether the non-traditional models researched in this project, when effectively put into practice, can achieve this, nor what these models might look like. Thus, further research on audience reception of the traditional and non-traditional model-based stories is needed and is explored in the next chapter.

CHAPTER 4 – Digging deeper: Uncovering audience opinion on science journalism stories based on theoretical models of science communication

Qualitative research studying science journalism and the experiences of its journalists has commonly addressed "the audience" as an important theme, as it is well known the perceptions journalists hold of their audiences impact how they produce their stories (Amend & Secko, 2011). However, the literature suggests science journalists have a very broad definition of who their audiences are -- commonly referring to them as "everyday" people who have basic or low levels of science literacy (e.g. Hodgetts et al., 2007; Hinnant & Len-Rios, 2009) – and instead use their own interests and scientific knowledge as measures of what the "imagined audience" (Reed, 2001, p. 285) might consider important and interesting. Thus, it has also been suggested journalists are ultimately unsure how their audiences make use of journalism to understand science (Reed, 2001; Treise & Weigold, 2002; Wilkinson et al., 2007; Hinnant & Len-Rios, 2009).

The four freelance science journalists participating in this project also described their perceived audiences in similar terms (Chapter 3), commonly referring to them as general news audiences with little science background. The story-writing guidelines in this project asked journalists to consider their audiences throughout the test story-production process – either as "passive spectators" in the case of the traditional-model stories or as more active or implicated members in the case of the non-traditional model-based stories. In doing so, the journalists made assumptions about their intended audiences and how they might perceive the produced test-stories, as was indicated in the journalist interviews covered in the previous chapter (see pages 68-69). However, without speaking to audience members about their opinions on the test stories, we risk failing to understand how science news stories based on models of science communication relate to audience interests, engagement and actions.

This chapter investigates audience reaction, opinion and interpretation regarding the model-based test stories produced in this project (Chapter 3; Appendixes II-V). It begins with an overview of the themes that emerged out of discussions in two focus groups – one including participants that rarely read science news, and the other including participants that often read science news. Specific attention is given to the differences between how focus group participants perceived and spoke about the traditional model-based stories (science literacy and contextual) and non-traditional model-based stories (lay-expertise and public participation). This chapter concludes with a discussion on what audience member opinions imply for the development of theoretical frameworks for improved science journalism.

Method

Focus groups with participants representing general audiences of science journalism were held due to their interactive nature and ability to capture real-life data in a social setting. Focus groups have been noted to "produce concentrated amounts of data on precisely the topic of interest" in a time-efficient manner, and elucidate a range of opinions through group interaction (Morgan, 1997). This method was also chosen for its ability to explore concepts that arise and distinguish trends, as well as the focus group's strength of producing group synergy and collective and collaborative thinking and problem solving (Krueger & Casey, 2009). Focus groups were therefore viewed as the best method to capture data on the perceptions, feelings, attitudes, and ideas held by participants on the science journalism test stories, thus providing a dynamic data source immediately from focus group participants (Vaughn et al., 1996).

In April 2011, two focus groups were held, with one group representing audience members who did not often engage with science journalism (once a month or less), and the second group representing audience members who engaged with science journalism on a regular basis (at least once a week). The decision to have two separate focus groups with these types of participants was made in order to elucidate a range of opinion from those familiar with current forms of science journalism as well as those unfamiliar with it. The focus groups were limited to five to six participants in order to ensure the groups were small enough to allow the opportunity for all participants to share insight, and large enough to provide diversity in perceptions (Krueger & Casey, 2009). The focus group participants were recruited from the Montreal area by random digit dialling based on public lists. As this process can create selection biases, this was minimized by stratifying the selected sample for the groups based on such things as age, gender, education, etc. For the purposes of this study, focus groups participants needed to fit certain general criteria: 1) they needed to live in the Montreal-area; 2) they needed to be English-speaking, either with English as their first language or fluency in English; and 3) they could not be working in journalism, sciences, politics, or public relations. For each of the groups, recruitment oversampled for seven to eight people, with a mix of age, gender and income in each group.

Focus groups lasted two hours and participants were compensated $45 each for their time and travel. The focus groups were approved by the Human Research Ethics Committee at Concordia University, and all participants were asked to give informed consent before participating in the study. Demographic stratification of the participants is shown in the Tables 4 and 5.

Table 4: Focus group A – Seldom engages with science journalism

	Gender	Age	Education
FGA1	Female	35-44	CEGEP
FGA2	Male	45-54	College
FGA3	Female	18-34	CEGEP
FGA4	Male	55+	High School
FGA5	Male	18-34	CEGEP

Table 5: Focus group B – Regularly engages with science journalism

	Gender	Age	Education
FGB1	Male	55+	University
FGB2	Male	18-34	CEGEP
FGB3	Female	45-54	University
FGB4	Male	35-44	University
FGB5	Male	55+	CEGEP
FGB6	Male	45-54	University

Focus group preparation and organization

Prior to the focus groups, participants were sent an information package that included details about the research project and their participation in the study, as well as the eight science journalism test-stories produced by the recruited journalist according to the model-based story-writing guidelines. The stories were split into two packages: one representing the four traditional model-based stories (science literacy and contextual) (Appendices II and III) and one representing the four non-traditional model-based stories (lay-expertise and public participation) (Appendices IV and V). It should be noted that participants were not made aware of the science communication models underpinning the stories (Chapter 1), or the differences between the stories. This was done in order to avoid guiding the focus group discussions in any particular direction. Participants were asked to read the stories as much as time allowed before attending their focus groups. If focus group participants did not have time to read all eight stories, they were asked to read a selection of the articles from the first group of stories, and a selection from the second group of stories. Participants were also given time during the focus group to reflect on the stories, or read the parts they did not have time to before their focus group.

Both focus groups were allowed to flow naturally in order to gain the richest data possible (Corbin & Morse, 2003, cited in Corbin & Strauss, 2008, p. 27). However, as focus group discussions have a tendency to go off topic, a focus group guide was developed to maintain the conversations and ensure key topics were discussed (see Appendix VI). The guide contained topics to be covered -- such as the participants' usual news habits and their perceptions of the traditional and non-traditional model stories based on the story-writing guidelines -- and suggested questions. Both focus groups were moderated by the researcher, and audio recorded for transcription. In order to ensure accuracy in the transcription stage, a note-taker was present during each focus group.

The focus group audio recordings were transcribed and then subjected to analysis that separately focused on opinions and themes within each of the two focus groups, as well as on the two story types (traditional and non-traditional). The qualitative software Nvivo 8 was used to aid in the coding process. As the examination of the focus group transcriptions followed a grounded theory approach, the analysis of the interview data was done in stages in which the data was broken apart and coded according to distinct identified concepts (Corbin & Strauss, 2008; Creswell, 2007). This process was repeated until the following four criteria were satisfied: 1) exhaustion of data sources; 2) saturation of themes; 3) emergence of regularities; and 4) overextension (Lincoln & Guba, 1985).

These themes were then reorganized and connected back to the story-writing criteria developed in this project in order to articulate the relationships between them, the test-stories, and audiences (Corbin & Strauss, 2008; Creswell, 2007).

Findings

The two focus groups were designed to gain insight on how audience members viewed the test journalism produced with model-based guidelines (Chapters 1 and 2) and their analysis was therefore broken down into major concepts that emerged from the two focus group discussions.

Purpose

Participants in both focus groups discussed what they thought the purpose of the test stories were. This concept included opinions on what the journalists' intentions were, as well as what end-goals the stories were aiming at, and resulted in a number of sub-themes between the groups.

A number of participants in the first focus group ("seldom reads" science journalism) viewed the purpose of both the traditional and non-traditional model-based stories as promoting environmentally-friendly initiatives and advocating environmental awareness among readers. Participants also alluded to the articles promoting a change in lifestyle. Expressions such as "eco-friendly" and "green" were commonly used by participants in this group to describe the stories' purpose:

> I think they're coming from a very green point of view. They're definitely not coming from fuel consumption. They're coming from an ecological point of view. I think all the articles are geared towards being more efficient. (FGA2)

However, rather than viewing the purpose of the test stories as promoting “eco-friendliness,” as participants in the first focus group did, participants in the second group (“regularly reads” science journalism) generally referred to the purpose of the test stories as promoting science and the possibilities presented by the research covered in the articles. This opinion was largely expressed with a cynical tone, especially when it came to the traditional model stories. Participants expressed doubt over the possibilities of the research covered in the articles, and at times even suggested the articles were written by the researchers themselves or as public relations tools:

> Especially the first part, the first few stories. He (the journalist) has a connection with the university, he wants to promote them, or find somebody to, I don’t know, give them money. (FGB3)

Such statements imply that the science cheerleading purpose that focus group participants viewed the stories – especially the traditional model stories – as having was seen as negative, causing some participants to even question the motives of the journalist, as well as lose a certain amount of trust in the science and research project.

Discussion on the purpose of the test stories as “informing” was limited to the “seldom reads” group, however participants discussed both traditional and non-traditional stories as having such a purpose:

> Well, the purpose was, like I said, to get information regardless of the source of where it’s coming. (FGA4)

> You know, general information about biofuels and the use of corn and the cost, the food for fuel debate that’s coming online in the next few years. (FGA2)

Participants in both focus groups also referred to the purpose of the non-traditional model-based stories as showing the reality of the science beyond scientific terms. Participants discussed this concept as informing audiences by relating the science and scientific information by appealing to everyday experience, giving the science and the research a human face, or tying it to reality:

> The fact that it was not as abstract and it puts things into concrete situations, that helps us approach it more critically and take a stand on our own. (FGB2)

Articles that were viewed as having the purpose of “showing reality” were largely discussed positively in the two groups.

Although not widely discussed by all focus group participants, one member of the “seldom reads” group explicitly stated promoting discussion was the purpose of the non-traditional model-based stories. Although this viewpoint was not widely held by all focus group participants, it was discussed in detail by this one particular member, and then agreed upon by the other four members of the “seldom reads” group. The purpose of promoting discussion was spoken about in terms of the non-traditional stories appealing to audiences, getting them interested in the subject, and encouraging them to talk about and debate the subject and issues with others:

> I think they’re for the general public to kind of bring about a kind of a global discussion, like we’re having here, or like I had with my partner when discussing these articles. (FGA2)

This concept is of interest because it largely matches with the story-writing guidelines used by the journalists to produce the non-traditional model-based stories, and was brought up by a participant without probing or questioning leading in this direction.

Lacking information

Consistent among participants in both focus groups was the opinion that, while all articles contained information that was valuable, there were a number of issues and pieces of information that were missing to give a more complete picture.

In the traditional model articles, the “missing pieces” raised in both focus groups were the risks associated with the research project covered in the articles, the costs and details about the project’s funding, comparisons to other alternative fuel and bioenergy sources, as well as future directions and long-term implications of the research. In addition to these areas of missing information raised in both groups, members of the second focus group also articulated the non-traditional model-based articles lacked inclusion of differing opinions:

> I would like to hear more opposing voices from -- not the oil industry, because I don’t trust those people...But I would like to hear from the environment people, scientists, even economists, because there is also proof that whatever they’re doing now with the ethanol is that it’s costing actually more than producing oil. (FGB3)

Members of the “regularly reads” group also expressed that, due to these lacking pieces of information, they were skeptical about the research project itself. Thus, the focus group data seems to suggest the eight test stories did not make use of enough diverse sources, or were not extensive enough in their sourcing practices. With these areas of lacking information in mind, members of the second focus group also called for an overlap between the two types of test-stories, in order to have the scientific information of the traditional stories, combined with the real-world viewpoints present in the non-traditional stories:

> FGB2: Well I think that actually what would help a lot is if they were somewhat more mixed, because after reading the first group, I already had the information that helped me understand the second group more. And I think that may have had an impact on my judgement.
>
> Moderator: In terms of a stand-alone story, making it better, having the two types being mixed?

> FGB2: Yeah, absolutely. And there was some information that was in the one article and then wasn't in the other; alone they wouldn't have had as much of an impact than if they were together.

> FGB6: The first part was too technical and dry for me. The second part I could relate to. If you combined everything together it would be a lot easier.

Such concepts may suggest that the models of science communication investigated in this story, when operationalized in the production of science journalism, may not be sufficient on their own, and rather require overlap in order to take advantage of the most positive and best-received features.

Relevance

All participants in the two focus groups spoke about how the information presented in the test stories related to them as audience members. The most often discussed point of relevance in the traditional model-based stories was that of economic impact – that is to say the impact the issues and research discussed in the articles have on the focus group participants' own wallets (cf. see page 63 on how journalists view this issue). Members of both focus groups discussed this point in terms of the relevance the stories had to them as consumers, specifically consumers of fuel and energy.

> It relates to us in a lot of ways, because of the gas prices and a lot of people drive cars. (FGA5)

> Well, I mean, considering I filled up my car two days ago for $50 and it's half now, I mean this will pique anyone's interest. (FGB4)

When speaking about the non-traditional model-based stories, members of both focus groups said the articles were made relevant to them through the personal connections written about. These "personal connections" were spoken about in the context of relating to how "real people" are experiencing the science on the ground and its implications, or hearing different people's opinions on the science, and relating one's own perceptions to this:

> FGB3: It tells it as it is, where the town says, you know, don't play games with us. We've been played before. It's not going to work this time, unless you have something fundamental on the ground to show us. So I like that part.
>
> Moderator: Right, so it made it sound more real?
>
> FGB3: Yes, and more with somebody who experienced it on the ground. Not just stories from somebody.

These statements suggest that focus group members were able to relate to the non-traditional model-based stories that spoke about "real-world" experience of the science outside of the lab by using the voices of everyday people – or non-scientists and non-experts -- as sources. This may suggest relevance of such stories to audience members may be raised by using unscientific sources and experiences audience members can connect with, even if these experiences are not their own.

Engagement

A fourth concept raised by members of both focus groups was the different forms of engagement the test stories elicited from them. Although most of the discussion surrounding this concept occurred in connection with the non-traditional model-based stories, participants did allude to certain forms of engagement that occurred surrounding the traditional model-based stories.

Members of the "seldom reads" group said the main way they engaged with the science and issues brought up in all the articles after reading them was by doing further research on their own time, mostly on the internet. This was done by participants to inform themselves and find out more information on the science of biofuels and energy, as well as on different social, economical, and political implications:

> I think this is pretty good, because it allows you to go and do your little search on the internet. There are a lot of things in here that I did not know. Like for example, the percentage of ethanol that is being used, mostly by the United States. (FGA4)

One member of this focus group, speaking in context of the non-traditional model-based stories, added to this concept that his personal research based on the information in the articles also led him to be more politically engaged in energy issues, and resulted in him paying more attention to what stance political parties take on bioenergy. This suggests that while the articles may have lacked certain pieces of information, they did provide enough information to interest and motivate focus group members to do their own research and find out more on the issues covered in the articles.

In the second focus group, the data suggested the information in the test stories motivated engagement in the forms of discussion and debate with other people. This was discussed in the context of both traditional and non-traditional stories. Participants suggested that the information in the stories would be taken and used in further discussion with other people about the issues covered in the stories, as well as to debate and learn opinions on the issues, thus implying that the journalists were indeed partially successful in producing stories aimed at engagement:

> What I tend to do, especially in the scientific world, is I have a kind of framework that stuff hangs on, and then I feed stuff into it, and when I'm reading something or talking to someone, somebody I meet who's now in any of this, working in any of these areas, I'll be interested in finding out what he can teach me. (FGB1)

Style

Despite expressing that the information in the test stories motivated them to engage further with the science and issues, a common theme raised between the two focus groups was that story style affected the readability of individual stories. This concept touched on issues concerning enjoyment while reading the articles and clarity in understanding what the articles had to say. The type of language used in the articles was the main factor spoken about that affected a story's readability. Participants in both focus groups shared similar views of the language in traditional model-based stories, which was seen as being overly scientific or technical. This affected the readability of the stories in a negative way, as focus group participants said they did not find the reading experience enjoyable and could not really connect with the stories on a personal level:

> Well, I found the first ones had a lot of scientific terms, and I found that compared to the other articles, it was a little more -- it wasn't difficult, but it was a little less easy to read, because it had lots of different concepts without many explanations. (FGA3)

> I can't say that that is very attractive from a popular point of view. For the scientist, this is probably too simple to read, and he would disdain it. But, anything you're writing for the public has to be presented in a way which catches his or her imagination, get's them hooked on reading the rest. And if it doesn't, then it's a badly written piece. It should never have been written. (FGB5)

Although the information presented in the traditional model-based stories was viewed as interesting in itself, the style in which it was presented was viewed as being written in a scientific fact-based style, relying on "abstract" (FGB2) scientific concepts. Although such statements reflect the guidelines of the science literacy and contextual models (Boxes 1 and 2), the traditional model-based story styles were largely spoken about in negative terms, with focus group participants using expressions such as "stilted" (FGB5), "boring" (FGB6) or "painful" (FGB3) to get through to describe the reading process. There was a general sense that the traditional model-based stories were written in a style that made the information harder to understand and decreased readability, particularly because they lacked a story-line:

> I found the first one particularly had my mind running around in a convoluted path. It wasn't very well – it wasn't a logic that I could pick up. (FGB1)

Participants in both focus groups also generally seemed to agree that non-traditional model stories were more clearly written. Instead of using scientific language and concepts, participants discussed that the non-traditional stories relayed information in a language that was easier to read and understand:

> This is much better. I understand it more, they're explaining it more. I understand where everything is coming from, and how they are putting the budget for everything. So, I find that this article's better than the other ones. The other ones are more scientific and more – I understand it, but I wouldn't sit and read it. (FGA5)

Participants in both focus groups described non-traditional model-based stories as being more "personal" (FGB2), easier to relate to (FGB6), "real-word" (FGA3), and overall more enjoyable to read. It is interesting to point out, however, that when discussing the style of non-traditional stories, focus group participants tended to use immediate examples from the FSJ3's lay-expertise article that was written in a non-traditional, first-person point of view style discussed in the previous chapter. This implies the language and style based on scientific terms and concepts used in the traditional model based stories was not well received by focus group participants, while the more explanatory "real-world" or "everyday" language used in the non-traditional stories made them easier to relate to on a personal level, and was something focus group participants reacted positively toward.

Although the data suggest that this non-traditional style appealed to focus group participants more than the traditional journalistic, information-delivery styles used in the traditional model-based stories, one member of the second focus group said relying on non-traditional story-telling styles is not enough to improve science journalism. She said she felt that such story styles appeal mostly to emotion to get readers to pay attention to the article, but do not cover the whole picture or leave long-lasting impressions:

> I liked it. It's fine, it's not bad. But it's not the whole story. He's not going to convince me with that. So, it was a nice story, I read it, it was enjoyable, it was fun, but then the next day, I forget about it and I don't care.
> (FGB3)

Thus, the data suggest that, while non-traditional styles may appeal to audiences and hold their attention throughout the article, story style is not enough to keep readers engaged in the long-terms or have any effect on meaningful and continuing engagement or debate on the issues.

Audience

When asked about what types of audiences they thought the different stories were targeted to, participants of both focus groups did not describe the perceived audiences for the traditional and non-traditional model-based stories in many terms beyond "general," similar to how the journalists themselves described their perceived audiences (Chapter 3). While some participants suggested the traditional model-based stories were geared towards a more specialized audience with a science background due to the use of scientific terms and concepts, and the non-traditional model-based stories were geared towards the average reader with little science background in science, focus group participants, especially in the "regularly reads" group, had more to say about the audience considerations journalists should have made and were perceived to have not. For example, a number of participants suggested the journalists should have targeted their audiences better, and come up with a more defined image of who their readers were supposed to be:

> FGB4: (speaking mostly about traditional model-based stories) I guess it goes back to the point where, depending on who your target audience is, you can make it more scientific, more science versus less fact, and more to the general public...
>
> FGB5: I agree with what you said. You have to select your audience and try to figure out from experience which is the best way to reach them... I don't think anybody who wrote this has thought of who his target is. I can't picture what kind of target I would use that to send information out.

Another focus group member, when speaking about both the traditional and non-traditional stories, called on journalists – as well as "experts" -- to stop treating their audiences as below them, especially since the internet has shifted journalist-audience power relations by giving audiences access to more information and the ability to access this information on their own terms:

> They don't see that it's not the same like 50 years ago. People have more information, they have the internet and they can find any information they want. They don't just trust anybody anymore... And we know a lot about what's going on in the world. Journalists should talk to us like we're equal. Like we're at the same level, and don't play games and say it as it is, and put the whole story, from all the sides. (FGB3)

This suggests that, in order to interest and truly engage audiences with science journalism, journalists should treat their audiences in ways similar to those suggested in the non-traditional model guidelines, and position the audience as active members in the story whose input is sought after, and as stakeholders in the scientific process, rather than passive audiences.

Discussion

Based on the focus group results, it is evident that the model-based test-stories were each viewed to have positive and negative elements. Non-traditional model-based stories were largely viewed as aiming to connect the science to everyday experience and "reality" outside of the research lab by providing human elements in the stories readers could connect to. The expressed opinion that the information contained in the stories motivated readers to go on to do their own research on the issues, as well as engage in discussion with other people, indicated these articles also succeeded at promoting a certain level of audience engagement (Boxes 3 and 4).

Audiences felt the articles were relevant to them on a financial level in the case of the traditional model stories (in that the scientific research covered has potential implications for energy issues, which audience members currently spend a lot of money on), and on a personal level, in the case of the non-traditional stories. Journalists succeeded at this by demonstrating what the science means outside of the lab in the "real world" by using sources from outside of science to add "human elements" to the stories, a common practice in science journalism (Balasegaram et al., 2008; Hinnant & Len-Rios, 2009; Saari et al., 1998).

The focus group results indicated participants observed differences in story style between the traditional and non-traditional model-based stories, thus implying the journalists largely followed the style guidelines in their stories. The non-traditional model-based stories were viewed as being more enjoyable to read and more engaging, in that they were not heavy on scientific language and technical terms, and also used "real people" as sources beyond the experts connected with the research project. Focus group members also gravitated most to the lay-expertise story written by FSJ3 (Appendix IV), which was written in a non-traditional journalistic style that made use of literary tools such as a first-person narrative, and distinguished it from the other stories. Although the traditional model stories followed the style guidelines and took on a classic journalistic style focused on the science itself and aiming at informing audience members, they were not well received by focus group participants. They were instead viewed as "boring" to read, "stilted" and heavy in scientific language, and hard to follow due to a lack of storyline.

Traditional model stories were at times viewed as promoting a "green" angle, but members of the "regularly reads" group viewed them as promoting science and the research project itself. Although this partially falls in line with the model-based guidelines (Boxes 1 and 2), thus suggesting the journalists succeeded in representing the models in their stories, focus group members, particularly in the "regularly reads" group, viewed this in a negative light, and expressed opinions that suggested these articles were in fact written as public relations tools to gain support and funding for the project. This indicates that audience members questioned the journalists' motives in the traditional model stories.

All stories were viewed as lacking information and viewpoints on a number of issues, including risks associated with the research project covered in the articles, the costs and details about the project's funding, comparisons to other alternative fuel and bioenergy sources, as well as the future directions and long-terms implications of the research and differing opinions. Focus group members also indicated they felt the journalists writing the test stories often did not have a very good idea of who their audiences were. This is similar to what research has said about a lack of understanding science journalists have of their audiences and the ways in which they use science journalism to gain knowledge, if at all (Treise & Weigold, 2002). Audiences members added to this that the traditional "top-down" approach of journalism that seeks to deliver expert information and knowledge to audiences is no longer valid, in that the internet and digital media have given audiences more power to engage with news and information on their own terms. Additionally, although focus group members enjoyed the styles of the non-traditional stories more, it was also expressed that story style was not enough on its own to make lasting impacts on readers and truly get them to engage with the science and issues.

In addition to identifying positively- and negatively-received elements of all the model-based stories, focus group participants articulated they thought an overlap between the models would be most effective at addressing such shortcoming in the stories as the identified lack of information and viewpoints they felt were missing from the articles, while improving story readability through story-style. This is in line with research that has shown science communication efforts usually make use of overlapping features from a number of models, instead of resting solely within one strict framework (Brossard & Lewenstein, 2010), and also supports the need for developing a hybrid model that makes use of the overlapping positive features of the models investigated in this research, and expands on them in order to fill identified gaps (Leach et al., 2009; Logan, 2001).

Based on the focus group results, such model-guidelines can be improved by, firstly, gaining a better understanding of who "the audience" truly is beyond science journalists' perceptions of their "imagined audiences" (Reed, 2001.) Models can be improved to respond to the recurring critique that science journalism fails to engage audiences (e.g. Bubela et al., 2009; Nisbet & Lewenstein, 2002; Logan, 2001; Weigold, 2001; Nelkin, 1995) if such models are audience-centred, position the audience as active members in the story whose input is sought after, and as stakeholders in the scientific process, rather than passive spectators.

Focus group results indicate such models should position the science and research covered in the articles in a way that is relevant specifically to the identified audiences and allows them to connect with the issues on a personal level. Focus group participants expressed that this can be achieved on one level by including sources from outside of science in order to portray the science in a more "real world" setting that extends beyond the research lab. Additionally, the lack of information and further viewpoints in the articles identified by focus group members implies that models can be improved by extending sourcing practices beyond the experts for information, context and quotes (e.g. Nelkin, 1995; Hinnant & Len-Rios, 2009; Ward & Jandciu, 2008; Chew et al., 2006; Geller et al., 2005; Waddell et al., 2005; Conrad, 1999), and including as many "stakeholder" viewpoints (Brossard & Lewenstein, 2010) as possible that are relevant to the identified audiences.

This suggests that in order to interest and truly engage audiences with science journalism, journalists should treat their audiences in ways similar to those suggested in the non-traditional model guidelines, and position the audience as active members in the story whose input is sought after, and as stakeholders in the scientific process. The focus group participants also indicated that traditional journalistic styles that seeks to deliver information and knowledge from experts to readers in a top-down fashion are not effective at engaging readers, expressing that these story styles were not enjoyable to read and even created skepticism about the stories and the journalists' true intentions among a number of readers. Thus, improved models of science journalism should seek to move away from such traditional styles and innovate story-telling tools that aim at actively engaging readers. Finally, if the goal of such models is to both inform and truly engage audience members in the science and related issues, then improved models of science journalism should seek to tell audiences about the science, make it personally relevant, and appeal to the audiences' actions by indicating how they can get involved and increase engagement. An example of such a "hybrid" model of science journalism is explored in the following chapter.

CHAPTER 5 – Overall discussion

This chapter presents a final discussion the major findings of the works included in this thesis. This is complemented with a discussion of additional, associated findings regarding journalist training and education, as well as media and technology. These findings are subsequently used to propose a hybrid model of science journalism that is informed by the findings of this project's criteria development, story production, journalist interview and focus group research phases.

Major findings

In order to investigate the use of theoretical models of science communication in the production of science journalism, this research project formulated six story-writing criteria – purpose, focus, style, sourcing, audience and science – in order to produce story-writing guidelines based on four models of science communication. These guidelines were given to freelance science journalists who, based on their interpretations of these guidelines, were asked to produce science news stories on a research project involving bioenergy and genomics at Concordia University. These articles were then presented in two focus groups with participants representing members of news audiences from Montreal, QC, who were asked to reflect on and give their opinions about the test stories produced by the journalists.

To the researcher's knowledge, this thesis is the first to successfully address three aspects of research on science journalism in need of clarification (see Introduction): 1) the development of more theoretically informed and diversified guidelines for the production of improved science journalism; 2) the simultaneous and comparative research-based assessment of the use of multiple guidelines by professional science journalists; and 3) the study of the reception of test journalism based on the use of these guidelines. This cycle of study has successfully taken the topic of this thesis from theory to practice, and in this discussion, back to theory to improve and present a new theoretical model of science journalism for future research endeavours (further discussed below).

These efforts resulted in four major findings: 1) model-based story guidelines can be successfully created (see Chapter 1) and utilized (see Chapter 2) by professional journalists, who gravitate towards certain elements of a model/guideline based on their usual routines and practices (Chapter 3); 2) in the application of the model-based guidelines, participating science journalists largely maintained their usual practices despite some guidelines (Boxes 3 and 4) calling for non-traditional story-writing methods, a result that shows experienced science journalists tended to view classical journalism style aimed at transmitting expert information to audiences as the most effective story-telling method for science journalism; 3) in focus groups, audience members gravitated toward non-traditional approaches to science journalism, namely the lay-expertise model as well as the public participation model, as they presented science stories in non-technical language that was enjoyable to read and used sources, characters and contexts that audience members could relate to on a personal level; 4) science journalists' perceptions of their "imagined" audiences (Reed, 2001) are too vague (i.e. while journalists expressed their perceptions of the audience guided their story-writing, focus group participants were of the opinion the test stories indicated journalists were in fact unsure of who their audiences were) and thus require increased attention and definition. Below, these findings are discussed further as related to each of the six story-writing criteria (see Chapter 1) developed in this thesis:

Purpose

The purpose guidelines for traditional model-based stories aimed at informing audiences, either about the science itself in the case of the science literacy model, or the science as it relates to audiences in the case of the contextual model, which was found to largely be reflected in the test stories produced and in the journalists' descriptions. This result seemed to be in part connected to the fact that a purpose of informing was clearly echoed in the typical practices of the four participating journalists, as indicated in the pre-interviews (Chapter 2). However, the traditional model stories that took on this purpose of informing were generally not received well by the focus group participants who were of the opinion the articles were either promoting eco-friendliness or a "green" angle, or cheerleading science as a public relations tool to gain support for the research. No evidence was garnered from the interviews with journalists to suggest this was indeed the case. But it is intriguing to speculate on why an informing purpose, which is traditionally seen as objective and removed (Logan, 2001; Nelkin, 1995), was viewed as promotional in this instance. This may be due to the fact such stories relied on scientific experts directly associated with the research project covered as the main sources, thus overlooking other issues and sources of information, causing focus group members to question the true intent and affiliation of the journalists. On the other hand, the purpose criteria for the non-traditional models asked journalists to write the stories with an aim of empowering local communities in the scientific process, in the case of the lay-expertise model, or promoting active engagement with the aim of supporting democracy in the case of the public participation model. Although it was difficult to discern whether these guidelines were followed by the participating journalists, as they often had difficulty articulating their story's purpose and focus discretely, the journalists' descriptions indicated they did view their non-traditional model stories as going beyond informing audiences. Nevertheless, these guidelines were not consistently applied in the test stories, which instead often continued to simply take on an informing purpose couched in what the journalists saw as "active engagement" through "good writing." Still, focus group participants viewed these articles as having an additional purpose of promoting discussion, which was spoken about in positive terms and viewed as more effective than the traditional model stories. The difference between the traditional model-based stories and non-traditional stories in this case seemed to be tied to the language used in the stories (scientific and technical versus simple or "everyday") and the types of sources used (experts and scientists versus community members and "real people).

Interestingly, this suggests a model of science journalism that mixes the purposes of the traditional and non-traditional models by informing and relating the science to real-world contexts to may be successful at both increasing audience members' knowledge about the science as well as informing them about what implications their actions can have, and encourage further engagement with the issues in the forms of personal research and discussion with others.

Focus

The focus in the traditional model stories was to be on the science/research itself for the science literacy model, or the science related to populations/audiences in the case of the contextual model. This was largely reflected in the test stories, for example with the science literacy stories focusing on the research project itself while emphasizing the "wow factor" of the science (Appendix II), or the conflict raised by the "food for fuel" debate and financial issues in the contextual stories (Appendix III). While the focus group members did view the traditional model stories as somewhat relevant to them due to the financial implications (specifically money spent on personal energy costs and transportation fuel), these were seen as lacking focus on such issues as the risks of the science, costs and funding details for the research project, comparisons to other alternative fuel and bioenergy sources, future directions and long-terms implications. These gaps in the stories caused skepticism and even apathy in the sense that the research was deemed potentially unimportant or inconsequential.

The non-traditional story focus guidelines asked journalists to focus on community attitudes on issues related to the science and a community dilemma with answers coming from within the community in the case of the lay-expertise model, as well as the processes behind the science, the consequences of the choices made and a community dilemma that needs all voices to be solved correctly in the case of the public participation model. The stories written indicate focus in the non-traditional stories was still placed on the science itself, but was balanced with community and real-world implications (Chapter 3). However, as with the traditional stories, focus group members expressed they felt there were still too many issues and too much information lacking in the non-traditional articles.

Such results suggest story focus guidelines were unsuccessful in meeting the needs of the focus group members, which is perhaps not surprising given that the participating journalist expressed difficultly with how to make use of this criteria

(Chapter 3). This suggests an area for future improvement, where a revised story focus guideline provides guidance on how to account for many more areas and issues related to and impacted by the science covered in the articles in order to truly engage readers., This implies a model of science journalism should expand sourcing practices from a focus on experts (Nelkin, 1995; Hinnant & Len-Rios, 2009; Ward & Jandciu, 2008; Chew et al., 2006; Geller et al., 2005; Waddell et al., 2005; Conrad et al., 1999) to a focus on including more community member voices as "human elements" (Balasegaram et al., 2008; Saari et al, 1998), as well as more social elements, risk factors, economic implications, policy, etc. in order to provide a fuller picture. This suggestion must balance the participating journalists' expressed opinions that a 500-word print story is limited in the viewpoints it can include (Chapter 3). This is elaborated on later in the discussion with reference to additional media technologies, specifically the internet, as a way to counter this obstacle.

Style

The guidelines for the science literacy and contextual model stories asked the journalists to follow a "traditional information-delivery style" reflective of the transmission view of communication (Leach et al., 2009; Carey, 1989), which was reflected in the test stories and journalist interviews. As previously mentioned, this adherence may be connected to the four journalists participating in the project expressing their usual practices follow a "top-down information-delivery" style (Chapter 2). However, focus group members consistently reacted negatively to this type of story, expressing that use of scientific and technical language and lack of story-line negatively affected readability.

The guidelines for the non-traditional models asked the journalists to produce their stories in styles that reflected active engagement or the mapping of stakeholder viewpoints. These guidelines purposefully did not elaborate on exactly what such a story style could entail (see Chapter 1, Boxes 3 and 4) so as to gain information on how the participating journalists would innovate with these models and to provide some freedom and flexibility. However, three of the four journalists showed some reluctance to write outside of classical journalistic style. It is interesting to note that the one journalist who did move beyond classical journalism style did not have a formal background in journalism and expressed that he treated this writing process as an "experiment" to try something new. This finding may be attributed to the fact the journalists have their already-established sets of norms and practices (Nelkin, 1995; Amend & Secko, 2011) that they use in their daily work, which in turn prevented them from writing in styles outside of traditional journalism despite, importantly, being given the freedom to do so in this project. Caution, of course, is needed in terms of interpreting whether the instructions provided to the journalists simply did not emphasize this freedom clearly or strongly enough, despite methodological attempts to imply in the guidelines that non-traditional styles should at times have been used, and asking the journalists to situate themselves in the model-based guidelines rather than in their usual routines and practices.

Regardless, focus group members gravitated to the one story with a non-traditional style most (see FSJ3's lay-expertise story in Appendix IV), expressing that it was enjoyable to read, and that the inclusion of "real people" – community members with experiences tied to the science rather than scientists, researchers and other experts – as characters made the story personal, relatable, and more "real-word." However, although positively received, focus group members did add that such a story-style was not enough to truly keep them engaged in the issues, as they felt such an article appealed to emotions while disregarding other important issues and sources of information. Such results suggest more innovative story-telling styles that push the boundaries of classical journalistic writing styles made the reading experience more enjoyable for audience members in this project. This also suggests the journalist who wrote this particular story applied all six criteria of the lay-expertise model guidelines and managed to effectively represent this model in journalistic practice, which audience members responded positively to.

Sourcing

The traditional model sourcing guidelines asked journalists to keep experts as the main sources of information, while other sources such as community members or organizations were to be used only to provide background and context. The test stories mostly reflected these guidelines (see Chapter 2), as it was expert voices that provided and legitimized the information in the articles, however community sources for background information in the contextual stories were lacking. Focus group members largely viewed this emphasis on expert sources as causing holes in the stories due to lacking information and viewpoints, which in turn caused skepticism about the journalistic articles as well as the scientific research. This is in line with wider literature that has critiqued science journalists for not presenting a range of opinion (Holtzman et al., 2005).

For the non-traditional stories, journalists were asked to place sources from outside of science and experts, such as lay-people and lay-experts, community members, leaders and organizations, on the same level as scientific and expert knowledge, and explore all stakeholder knowledge with a goal of empowerment, engagement, and solution-seeking. While this was not consistently applied across all non-traditional stories, the previously mentioned article (FSJ3's lay-expertise story) that did follow these non-expert-centred sourcing guidelines received the most positive comments from focus group members. Nevertheless, the lack in additional sourcing diversity in all non-traditional stories left focus group members feeling the stories missed covering certain issues they wanted to hear more about, the same as those referenced under the focus criteria above.

These results suggest the purpose, focus, and sourcing criteria were closely connected to the journalists' interpretations thereof, as the focus and purpose of a particular story drove what sources were included in it (cf. Amend & Secko, 2011). Both traditional models of science journalism that included scientific and expert sources, and non-traditional models that placed emphasis on sources from outside of science revealed gaps in the information and viewpoints presented in the stories, as expressed by focus group participants. This implies that an improved model of science journalism that aims at engaging audiences and providing a fuller picture of the science and its implications should go beyond using experts sources to include sources relevant to the issues and concerns held by audience members, while nevertheless not abandoning what experts can provide to a story as related to addressing these concerns.

Audience

Journalists were asked to treat their audiences either as "spectators" in the case of the traditional models, or actively include audiences in the story in the case of the non-traditional models. The guidelines for the traditional models were reflected in the test stories, as audience members remained outside of the story. Journalists tended to describe their audiences in very broad terms and held the common belief that audience members had low or basic levels of science literacy and were generally reluctant to read science stories, but were nevertheless curious (see Chapter 3; cf. Hinnant & Len-Rios, 2009; Reed, 2001; Hansen, 1994). Although the guidelines for the non-traditional model stories asked journalists to include audiences in their stories by seeking their input, three of the four journalists continued to treat their audiences as spectators (Logan, 2001). Again, the one journalist that did include members of the intended audience in the story had no formal journalism background. This, as well as the other journalists' own explanations (see Chapter 3), suggested the journalistic norm of treating audience members as spectators and keeping strict boundaries between these groups stood in the way of the journalists taking on a different, more collaborative approach.

Focus group members suggested the journalists did not have a good understanding or definition of who their audiences were, which thus affected the quality of their stories. Focus group members called on journalists to really think about, research and define who they are writing for in order to improve audience reception and engagement. Nevertheless, both the traditional model and non-traditional model stories did peak the interests of a number of focus group members and led them to further engage with the material and issues through personal research on the topics, mostly done on the internet, as well as discussion with others. Some focus group members suggested reading the stories also motivated them to become more eco-conscious. These forms of engagement were undertaken outside of the context of the articles, and focus group members thus underscored the fact that traditional journalist-audience relationships have shifted (e.g. Brumfiel, 2009; Secko, 2009), specifically due to the internet, which allows audience members to interact with information on their own terms. Focus group members called on journalists to revaluate their position and change their norms and practices in order to reflect this shift.

Such finding suggests that if journalists truly want to engage their audiences in science journalism, they need to seriously consider who these audiences are beyond their own images of the "imagined audiences" (Reed, 2002). Thus, there is evidence that any improvement to a model of science journalism cannot help but more deeply engage with approaches that are audience-centred and seek to address the questions and concerns of these audiences. Based on focus group discussions and recent research (e.g. Brumfiel, 2009; Secko, 2009), in order to address such audience concerns, science journalism should make use of the tools offered by the internet, including science blogs, as they are widely available and accessible, and present opportunities to extend the narrative of science stories by including audience concerns, questions and voices (Secko, 2009).

Science

The guidelines for the traditional model stories asked journalists to position science in their stories as fixed and certain (Brossard & Lewenstein, 2010, Nelkin, 1995; Leach, et al, 2009), valuing expert and scientific knowledge over other forms of knowledge, which was reflected in the traditional model test stories, as journalists used scientists and experts as the main sources of information and positioning it as able to offer potential solutions to energy issues without questioning such claims. Focus group members largely viewed the non-traditional stories in a negative light, expressing that they were heavy in scientific and technical language and did not include other issues and sources of information outside of science, causing participants to be skeptical about the intentions of the articles and the implications of the research itself.

On the other hand, the lay-expertise and public participation guidelines asked journalists to position science as uncertain and embedded in society, with other forms of knowledge also considered legitimate. Journalists said this was done by balancing the science with other issues and sources in the stories, and did not treat science solely as able to provide solutions, but rather tempered the research project's expected implications. Focus group members expressed that the non-traditional stories were less heavy on scientific language than the traditional models, and instead used everyday language that they said made the articles easier and more enjoyable to read. Additionally, such stories were seen as including voices and viewpoints from outside of science, which allowed audience members to relate to the stories and make personal connections to what the science might mean to them.

Such findings suggest that an approach to science that views it as uncertain and embedded in society leads to science journalism articles that are easier to understand and relate to by audience members. Thus, improved models of science communication may benefit from positioning science in this way, using style and sourcing practices that reflect this.

Additional findings

Two additional, associated findings are worth mentioning. First, the majority of journalists participating in the project seem to have tried to apply the story-writing guidelines and criteria of the non-traditional lay-expertise and public participation stories by using traditional journalistic practices. That is to say, the journalists often wrote their stories in a classically journalistic fashion and, as evidenced in the interviews, tried to map the non-traditional guidelines onto the traditional journalism frameworks, i.e. they used the same routines and practices and held many of the same norms in the non-traditional stories that they did in the traditional stories. There is, of course, a constant struggle between traditional journalistic norms and emergent norms (Allan, 2009) that requires careful consideration in terms of why a journalist may want or need to abandon traditional practice for new forms of journalism. Thus, in order to ensure journalists adopt such non-traditional models, prior training in the application of such models may be required to counter conflicting traditional journalistic routines and practices.

Second, it is also worth briefly noting that although the participating journalists did not place emphasis on other forms of media beyond print, focus group members continuously referenced the internet and digital forms of journalism as being increasingly influential in their own personal research on topics that pique their interest, and the ways they engage with science news and information. Although this research did not investigate news media outside of print journalism, any new models of science journalism should carefully consider this shift in technology, as this also represents a shift in journalist-audience relationships (Brumfiel, 2009; Secko, 2009).

Preliminary theoretical framework: A hybrid model of science journalism

The models utilized and developed in this thesis were designed to individually respond to the many, varied and recalcitrant critiques of science journalism. For example, the science literacy model attempted to address oversimplification and extrematisation (Nelkin, 1995) and the exclusion of scientific details such as methodological specifics

(Boyce, 2007); the contextual model attempted to addressed the critique that science journalism fails to inform audiences and equip them with the knowledge and understanding to make personal decisions related to their safety, health and environment (Brossard & Lewenstein; 2010; Nelkin 1995); the lay-expertise model attempted to address observations that science journalism presents scientific research with "excessive certainty" (Boyce, 2007) and ignores voices and knowledge from outside of science (Brossard & Lewenstein, 2010); the public participation model attempted to address an identified failure of science journalism to engage publics in meaningful dialogue about scientific issues (Dentzer, 2009; Bubela et al., 2009; Racine et al., 2006; Russell, 2006; Logan, 2001; Weigold, 2001; Nelkin, 1995).

In this study, each of the models was put on an even keel, with none prioritized over the other, in part to evaluate their strengths and weaknesses in comparison to each other, since this initial research step has never been undertaken. From this approach the following strengths and weaknesses became clear:

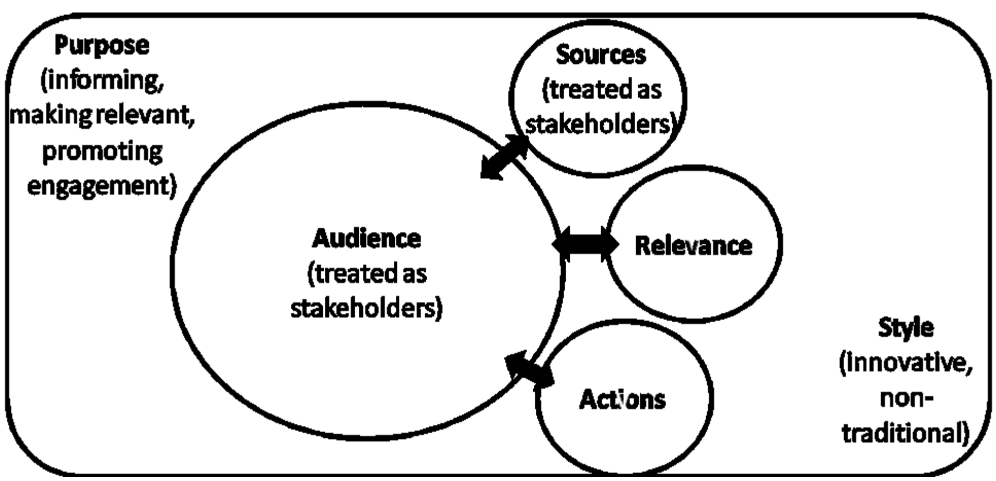
1. The science literacy model had strengths in communicating scientific information and detail, however failed to make this information relevant to audiences.
2. The contextual model had strengths in communicating scientific information in more "real world" terms, but showed weaknesses in targeting specific audience contexts and making this information truly relevant to readers.
3. The lay-expertise model showed strengths in including sources beyond science as the main providers of information that audience members could connect to, but displayed weaknesses in representing a wider range of opinion and sources of information.

4. The public participation model exhibited strengths in getting audience members to engage with the articles and the information contained in them, but also showed failures in representing opinions and knowledge from a wider range of stakeholders.

It also became clear that stories based on the science literacy, contextual, lay-expertise or public participation models did not have story-writing criteria consistently applied throughout this study, and were differently received among focus group participants.

Taken together, these finding nevertheless provide an opportunity to adapt and prioritize the strengths of each model to propose a hybrid model of science journalism (Figure 2), informed by the results of this project's four research phases.

Figure 2: Preliminary theoretical framework for a hybrid model of science journalism



This hybrid model has as its **purpose** to counter the critiques of the original four models by aiming to inform audiences about the science and how it affects them, as well motivating them to become engaged with science by appealing to the audiences' actions and indicating what they can do to become more involved with the issues. Although such a model needs to take into account that science does play a central role in science journalism and cannot be completely left out in favour of lay-expertise or opinions, the science should not be presented as the only solution and should be balanced with other factors.

The focus groups in this project revealed that, although there were many cases where the journalists thought they were effectively writing science stories that engaged people, focus group reception indicated otherwise. Focus group members also called on journalists to make an effort to gain a better understanding of who exactly their audiences are, as well as reconsider their place in the shifting journalists-audience structures caused by the internet and digital media, and reconsider their norms and practices accordingly. Thus, in order to respond to the identified lack of understanding and definition of who audiences are (Hinnant & Len-Rios, 2009; Reed, 2001; Hansen, 1994) this hybrid model is **driven by audiences** themselves, who are treated as stakeholders in the scientific process. In order to truly ensure this audience-driven criterion is fulfilled, journalists need to gain a more defined image of their audience and not rely solely on their own images of the “imagined audience” (Reed, 2001), for example through marketing segmentation (Brossard & Lewenstein, 2010) polls, and increased active community engagement, as for example advocated by public journalism (e.g. Glasser & Craft, 1997; Haas, 2007; Rosen, 1996).

In order to address the lack of sources, viewpoints and opinions expressed in the focus groups, this hybrid model should take as many stakeholders into consideration as possible, and use them as **sources** in the story-production process. As this model is audience-centred, journalists should take their questions and concerns about the science and its implications into consideration when going through sourcing processes. In order to respond to the traditional models' failure to make the science meaningful to audiences, journalists should seek to underscore the **relevance** of the issues to their identified audiences by asking such questions as: How can the audience relate to the science? How does the science affect their lives? What does it mean? Why should they care once they're done reading the article? This last point leads to the **actions** criterion of this model, which attempts to respond to the criticism that science journalism has failed in truly engaging audiences. Once audiences are shown why they should care about the science and related issues beyond reading the article, science journalism based on this model should go one step further by keeping the audiences' actions in mind and demonstrating that they can actively become engaged with the issues by suggesting how (e.g. public engagement event listings, how to become involved on a political level, ways they can interact with the scientists/research community, what they can do at home, etc.). In including as many angles and sources as possible to address audience questions and concerns, this should be done without the journalism becoming activism (i.e. by not limiting focus to one aspect or cause).

Finally, science journalism written according to such a hybrid model should move away from classic journalistic style, as focus group results indicated such a style did not have a lasting effect on participants in terms of interest and engagement. The journalists participating in this project also expressed that a 500-word traditional journalistic article is limited in how many issues, viewpoints, and sources it can include. New styles of science journalism need to be innovated in order to move away from traditional norms to

1) appeal to audiences, and 2) in order to incorporate the criteria of such a hybrid model, as traditional print journalism styles may be too limited to do so. This research suggests that classic journalism style is not the most effective venue for non-traditional science story models. Such styles have yet to be formulated, however may include traits and tools more commonly seen in literature, as well as non-liner storytelling made possible through digital and online journalism.

Thus, such a hybrid model of science contains six story-writing criteria, which are outlined in Box 5.

Box 5: Story-writing guidelines: Hybrid model of science journalism

Audience: Stories should be audience-centred in the events and issues they address. Journalists should aim at gaining a better understanding of who exactly "the audience" is beyond their own perceptions. Audience members are not considered passive spectators, but are rather active members in the story. Thus, journalists should aim at creating a dialogue with audiences.
Purpose: Such stories should seek to inform these audiences about the science as it relates to them and promote active public engagement by suggesting how this can be achieved.
Style: Story-style should move away from traditional "top-down" journalistic style and use story-telling tools that convey active engagement and map stakeholder viewpoints.
Sources: Stakeholders relevant to the audience should be included in the story. While scientists and community members should be included, sourcing practices should expand to sources able to address additional audience concerns and questions.
Relevance: The science should be made relevant to the audience on a personal level. The story should tell audience members why the science is important and what implications it has for them.
Actions: In order to foster public engagement, the story should propose avenues for audience members to become involved. The story should thus tell audience members what they can do.

Strengths and limitations

Limits

Before concluding, it is worth making a few final points about the limitations of this project, as well as its strength and future directions. Firstly, although it was science communication and journalism literature that informed the criteria development process, it should be noted that the researcher's own background as a journalist may have influenced assumptions on how the guidelines should have been applied, and on how the story-writing criteria were linked to the four models investigated in this study. This was especially important in the test-story analysis phase, as the researcher's own interpretations guided the analysis of the test articles, as well as the interpretations of how and whether journalists applied criteria to their work during the project. Readers are thereby cautioned to consider this background of the researcher when evaluating the reported data and its discussion.

Secondly, as the produced model-based guidelines were intended to be given to experienced, working journalists with already-established personal journalistic routines and practices, the guidelines needed to relate to recognizable journalistic concepts that would appeal to the journalists. Although the guidelines – specifically the ones based on the lay-expertise and public participation models – implied journalists would need to break with traditional journalistic practice, they were not explicitly asked to do so. The fact that the results demonstrated the journalists typically would not abandon their usual routines may have been, in part, related to this limitation.

Third, focus groups discussions indicated that a reading bias may have existed, as the focus group members expressed they read the traditional model stories before the non-traditional model stories. Thus, focus group members may have taken information away from the traditional model stories that affected their interpretations of the non-traditional model stories, which should temper the interpretations of the focus group results. While outside the scope of this thesis, future work with using a randomized story order and focus groups conducted to data saturation are needed to address this methodological limitation.

Strengths

Although this study was restricted in a number of areas – namely to print journalism, to freelance journalists as opposed to full-time journalists, to only two audience focus groups, to four models of science communication, and to a Canadian context – which should temper the interpretations of this projects' results and implications, this study exhibited a number of strengths. While there has been significant research done that critiques science journalism, the literature on how to improve the identified problems of science journalism and the practical use of science communication models in the production of science journalism has been limited or non-existent. This research sought to fill this gap. To the researcher's knowledge, this is the first project that went beyond mapping science communication models on to existing science communication efforts (Brossard & Lewenstein, 2010), and developing science journalism story-writing criteria (Secko, 2007), and actually recruited working journalists to produce test stories based on the models. By gaining insight into journalists' experiences using the models and their associated criteria to write journalism, this research helped shed light on how journalists functionally make use of models, and hence how science journalism may be produced from within various theoretical boundaries. Furthermore, by investigating audience reception of the stories, this research shed light on how audience members engaged with science communication models and used them to gain knowledge and understanding, thus responding to the identified lack of understanding on how audiences make use of science journalism (Treise & Weigold, 2002). The combined results informed a preliminary theoretical framework for a hybrid model of science journalism, which responds to the previous observation that science communication efforts do not usually rest strictly within one theoretical framework, but instead make use of features from a number of different models (Brossard & Lewenstein, 2010).

Finally, although the hybrid model of science journalism presented here is a preliminary framework that requires further investigation, it suggests directions for best practices in science journalism that can provide working journalists guidance on how recurring critiques identified in the literature may be answered, and – as this research suggests the adoption of such a non-traditional model requires prior training to counter traditional journalistic routines and practices -- provides information useful in the education and training of future science journalists.

Future directions

The use of the combined methodological approach may help future research further develop models of science journalism, and advance investigations of how science journalism is produced and experienced by journalists and audience members. While this thesis project was restricted to print science journalism for a number of reasons – namely in order to provide a focused starting point for such research and because the critiques present in the literature were largely aimed at print journalism -- future directions may extend to other forms of science journalism, specifically digital forms and the implications of the internet, and may investigate further theoretical models of science communication in order to expand on the preliminary framework presented here. In the future, research using a methodology similar to this project's would benefit from training the journalists in how to use the models beyond traditional norms and practices, rather than just leaving it up to interpretation. Also, while the hybrid model suggested here is admittedly idealistic for print science journalism limited to 500 words on a static printed page, it may be realistic when viewed in the context of digital media, multimedia and the possibilities of the internet. Focus group members indicated they used the internet to get their science news, and are disenchanted with old journalist-audience relationships that are no longer valid in an online context (Secko, 2009). Short-form print may not be the most effective venue for science journalism. The hybrid model suggested here calls for a more collaborative journalist-audience approach to science journalism and may benefit from the technological story-telling tools presented by digital forms of science journalism. Thus, future research would benefit from investigating models of science journalism in an online, digital, or multimedia context.

Final conclusion

This thesis project set out to investigate the practical use of science communication models in science journalism production. By building on limited past research (Brossard & Lewenstein, 2010; Secko, 2007) and reviews of the literature, this project began by developing six story-writing criteria for science journalism stories, and then used these to formulate guidelines for story production based on four models of science communication (Chapter 1), recruited journalists to test these guidelines by writing science journalism stories (Chapter 2), interviewed the journalists on their interpretations of the guidelines and applications (Chapter 3), and presented the test stories to focus groups representing members of general news audiences, where participants discussed their opinions on and reception of the stories (Chapter 4).

The combined findings were then used to inform a preliminary theoretical framework for a "hybrid" model of science journalism that integrated data from the story criteria and model guidelines, the journalist interviews, and the audience focus groups. Such a model is audience-centred, and seeks to counter critiques of science journalism failing to promote meaningful dialogue on scientific issues (Dentzer, 2009; Bubela et al., 2009; Racine et al., 2006; Russell, 2006; Logan, 2001; Weigold, 2001; Nelkin, 1995). While the data presented in this thesis are too limited to suggest any of the four models of science communication investigated should be discarded, the results show further refinement is needed. Thus, in conclusion, rather than abandoning past models of science communication, this new hybrid model of science journalism builds on them by taking the best of the four models investigated here and leaving out the worst, thereby recommending science journalists transition to forms of reporting that make science relevant to the personal lives of audience members by, 1) gaining a true understanding of who these audiences are; 2) considering the questions, concerns and opinions of these defined audiences throughout the story-writing process; 3) promoting active engagement in the issues by appealing directly to their actions through providing audience-relevant examples of what can be done; and 4) revaluating journalistic norms and practices in order to achieve the purposes of such a model. This model, while preliminary, provides a foundation for best practices in science journalism and, by situating criteria presented in the hybrid model against past models of science communication, can help future research further develop models and methods to improve the quality of science journalism.

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APPENDICES

APPENDIX I: Research project background 'press release'

Concordia University scientists make genomic research advancements for biofuels

The need to move away from fossil-fuels has never been greater. In this move towards a bioeconomy, interest in the potentials of converting the fibrous, woody, and generally inedible portions of plants (cellulosic biomass) into fuel is rapidly increasing. However, this process is currently limited by inefficiencies, such as a lack of enzymes that are effective at converting woody plant materials into simple sugars. These sugars are the basic building blocks required to produce advanced biofuels and biochemicals that can turn agricultural and urban waste into products and fuel.

Dedicated scientists at Concordia University in Montreal part of the Genozymes for Bioproducts and Bioprocesses Development project are making important advancements in genomic research to identify, analyze and develop potential enzymes in fungi that can be used to convert plant material into biofuels, biochemicals and other products for industrial use. Using fungi as a natural laboratory, they are searching for the proteins needed to do this. Fungi play a natural role in decomposition as they break down woody biomass -- such as tree limbs, tops, needles, leaves, bushes and shrubs -- into sugars, a process which they aim to harness and duplicate.

This research will provide the cornerstones for the development of large-scale industrial biorefineries that process biomass into biofuels and biochemicals. The project also plans to develop enzyme supplements for use in cattle feed, reducing the amount of grain necessary to ensure a nutritious feed product. This development could stabilize the cost of feed for farmers and cut food costs. The enzymes could also help the pulp and paper industry reduce the amount of energy it uses and the pollution it generates.

APPENDIX II: Science literacy model-based test stories

Applying high tech methods to the study of lowly fungi **(FSJ2)**

Even by the lesser standards of a fungus, *Aspergillis niger* would seem unlikely to win any popularity contests. It may be best known for causing the black mold that sometimes infects our fruits and vegetables, making it one of the less desirable agents to be commonly found in the soils around us.

Nevertheless, Concordia University Justin Powlowski has cast *A. niger* as a star participant in an ambitious exploration of the unique biochemical capabilities of fungi. The project, Genozymes for Bioproducts and Bioprocesses Development, features this particular fungus in the study of how genes function in dozens of different fungi.

More specifically, *A. niger* is the test-bed where genetic material from those other fungi is implanted and then exposed to particular compounds that these species typically consume. Powlowski is hoping to spot some of the key enzymes that play a part in way fungi break down these materials, revealing the dynamics of intricate processes that have largely eluded investigators.

Some of those processes could have significant industrial implications, according to Concordia biologist Adrian Tsang, who is heading up the project. He points out that fungi marshal a wide array of enzymes to decompose everything from organic waste on the forest floor to plastic deposited in municipal landfills. However, few of these complex chemical interactions have ever been formally analyzed.

“Many of the enzymes being used in industry have been isolated from fungi,” he says. “What is different is that we’re doing it on a much larger scale.”

Tsang adds that the resulting insights could indicate how material that is currently regarded as waste, such as the straw left behind on harvested fields, could be refined into a fuel suitable for engines that would normally run on gasoline. Similarly, the work could turn up more environmentally benign enzymes to replace the toxic chemicals currently used to turn wood pulp into paper.

Such prospects have generated a great deal of support for the project, which has received more than $17 million in funding from Genome Canada, as well as bringing together seven distinct institutions. They include three universities (Concordia, McGill University, University of Calgary), two government agencies (Quebec's Institut national de la recherche scientifique and Agriculture and Agri-Food Canada), and two private sector partners (the Netherlands-based biotech firm DSM and FP Innovations, a Canadian pulp and paper research body).

The results will also demand a great deal of computing power and expertise. The project is to sequence the complete genome of some 30 fungi, which means identifying all the proteins contained in their cellular structures. The handling of such data, a relatively new discipline known as bioinformatics, will make up a significant portion of the project's activities.

"You need the bioinformaticians to gather things together and look for patterns," explains Powlowski. "If you can show that an 'unknown' gene is being expressed specifically in response to wheat straw, and not in response to glucose, then you have an idea that the organism is producing it for some reason and it may have some activity that we don't know about. That's where you could potentially make some exciting discoveries."

Ethanol: Fermenting Change (FSJ3)

Imagine making beer out of wood chips, and you'll have some idea of the challenges facing researchers at Montreal's Concordia University.

It's not that the team of biologists and chemists is looking to develop some kind of ultimate I-am-Canadian brew; their goal is to extract ethanol from forestry and agricultural waste. But the quest is just as difficult.

To be sure, humans have been making ethanol – the correct chemical name for the active ingredient in beer, wine and spirits – for thousands of years. And we've been using the same fermentation process to produce ethanol specifically as fuel since the late nineteenth century.

But the sources we've traditionally used to make both drinkable and burnable ethanol have always come from substances we would otherwise consume as food: grapes and apples, for example, or corn, potatoes, and wheat. The reason is that all of these ingredients contain sugar in a very simple and soft state: starch. And fungi, the organisms that make fermentation happen, are very effective at breaking sugar in this form into ethanol.

Fermentation, however, isn't so easy when it comes to the woody branches those fruits grow on, or the stalks that support that wheat or barley. Sugar in these parts of a plant is stored as cellulose, a much tougher cousin of starch. And to make matters worse, cellulose is laced with lignin, the tough, stringy stuff that keeps tree trunks and plant stems standing straight. When sugars are locked into plants in this way, it's a lot harder for fungi to do their magic.

The Concordia team is part of an international effort to find fungi that can work on cellulose as well as or better than the fungi that currently work on starch.

It won't be easy – there are over 1.5 million different kinds of fungi. But the Montreal scientists are speeding the search using tools developed only in the last five years. The process begins with gene machines that can scan the DNA of scores of unfamiliar fungi at a time. Powerful computers then compare the blizzard of genetic information generated about each new fungus with the DNA structure of fungi whose capabilities in dealing with cellulose are already well known, looking for hints that suggest similar potential. It's like looking for a needle in a haystack – but with really good magnets.

The Concordia researchers then take the most likely candidates and run more detailed tests to determine if the potential indicated in the genetic profile can actually be realized in the lab. Samples of the fungi that pass these tests are then passed on to collaborators in industry who do pilot testing of the organisms' potential to perform at an industrial scale.

The search has global implications. Increasing ethanol production could help wean the world from its dependence on rapidly disappearing oil. But making ethanol the traditional way, using food crops like corn, hampers our ability to feed the world's growing population. How much better if instead we could use the corn itself to feed people, and make our fuel from the stalks it grows on – or any other kind of agricultural or forestry waste.

Beer from wood chips? Not so much. But at Concordia University, just the idea of fermenting plant waste is giving researchers a buzz – about a better future.

APPENDIX III: Contextual model-based test stories

Contextual story (FSJ1)

As some policymakers in the United States mobilize under a “food for fuel” debate over using corn and other staples for biofuels, researchers at Concordia University are working to inform the public that they don't plan to burn the food on your dinner table.

In partnership with industry and other universities, the researchers are breaking apart the genetic makeup of 30 types of fungi, trying to find the best chemical “spark” or enzyme to make natural fuels similarly effective to gasoline or diesel – and holding regular lectures to show the public their work.

“In our particular case, for the kind of ethanol we're looking to produce, we're not taking it from food stuff, but waste material,” said Justin Powlowski, a researcher and biochemistry professor at Concordia.

“It's the straw left over after you harvest the alfalfa crop, or we'd be looking at forestry stuff that gets thrown away anyway.”

Food for fuel hasn't quite hit the public radar in Canada, but it exploded in the United States four years ago after then-president George W. Bush said his country should generate 132 billion litres of biofuels in a decade to wean 15 per cent of American fuel usage off of gasoline.

With the United States' 430 million acres of cropland already heavily farmed, pointed out *Business Week*, it would be difficult to find the additional minimum of 50 million acres needed to fulfill Bush's wish.

“There's a whole range of different fuels out there with different benefits and impacts, like greenhouse-gas emissions or the fuel-for-food side,” pointed out Jeremy Moorhouse, a technical consultant for the Pembina Institute, an environmental policy group.

Moorhouse has heard of a number of different biofuels in development, with some of them just a few years away from commercial production.

Each one will need to be evaluated on its own merits with the watchful eye of governments and citizens, he said, to make sure they are being introduced responsibly into the world.

“(The fuel) could be coming from your backyard,” he added.

“People should be worried about this 'food for fuel' agreement – is your decision to drive a car actually increasing food prices somewhere around the world? That could be another tough decision for people to make.”

At Concordia, the researchers said they try to make that decision easier through lectures and demonstrations on the research.

“My fear is the public not having faith in what we do or what we say, and then we lose out,” said Adrian Tsang, a group researcher and the director of Concordia's center for functional and structural genomics.

Since Concordia researchers predict it will take at least a decade to get their research used in industry, keeping the public continually informed about this is one of the project's greatest challenges.

“The worry from the government and industry part of it is the public will lose interest,” Tsang said.

“Are we insulting the public by saying that, or is that the reality – why is the public not interested in things where we don’t have quick fixes?”

Fungi to Fuel our Future: Canadian Scientists (FSJ4)

In the increasingly quixotic search for new energy sources, Canadian researchers say the fungi in the stomach of Arctic muskox might have secrets that we can take to the fuel pump.

The scientists at Concordia University are turning to fungi – the relatives of mushrooms found in animal stomachs and on the forest floor – as tools to produce a new generation of ethanol-based biofuels.

At present, the ethanol added to gasoline in Canada is produced from corn and grains. New federal laws require that all gasoline sold in Canada contain at least five percent ethanol.

“There’s a lot of opposition to using food crops for producing fuel so that someone can drive their car,” says Concordia biofuels researcher Justin Powlowski, “What we’re interested in are residues of things that are harvested anyway,” including straw and forestry wastes, from branches to leaves.

As part of its renewable fuels initiative, the federal government is pumping millions of research dollars into the development of new second-generation biofuels.

The path to these new biofuels, say scientists, lies in discovering new enzymes. These are the molecules all creatures, including humans, use to digest foods. For many fungi, that food is wood.

“In nature fungi are the organisms that do most of the work,” decomposing woody materials says Concordia fungal researcher Adrian Tsang. “Over the past billion years these organisms have already evolved all kinds of tricks.”

Corn is almost pure starch, and thus relatively easy to break-down into the simple sugars which are fermented to make ethanol. However trees and grasses are mostly made from cellulose, a material that’s much more difficult to digest than starch.

The current “cellulose cocktail” of fungal enzymes used in industrial applications - from preparing pulp for paper making to stonewashing jeans - is based on a fungal enzyme discovered more than half-a-century ago. It was isolated by US military researchers in WWII in an effort to figure-out how to stop fungus from eating the military’s canvas tents.

Funded in part by Genome Canada, the Concordia researchers are using the latest gene prospecting technologies to search for fungal super-enzymes - those that can digest cellulose faster and more efficiently than existing ones. To date, the Concordia group has sequenced about 20 full fungal genomes, of the approximately100 fungal genomes sequenced worldwide. They've focused on well-known fungi, but are also searching far afield, including in the stomachs of animals, including muskox, that eat grasses and wood.

But don't expect to see a muskox symbol on a gas pump anytime soon.

"Gene sequencing is one thing," Tsang says. "Getting practical knowledge from it is quite another. I think it's going to be a continual incremental improvement, it's not going to be a Eureka moment."

The scientists are working with Ottawa-based enzyme producer Iogen Corporation to put newly isolated enzymes into action to see how they perform in the company's cellulose ethanol test facility, the world's first. Presently, Iogen is using wheat, oat and barley straw as its cellulose feedstock. The company website notes that its current fungal-derived enzyme technology can't be applied to softwood, the kind of trees that dominate Canada's forest industry.

APPENDIX IV: Lay-expertise model-based test stories

Science, Hearts and Minds (FSJ3)

I thought it would be the kind of science-meets-economic-development story that might give Bob Cloes a shiver of anticipation.

Bob is General Manager of the Community Futures Development Corporation, in Bancroft, Ontario. And if any town can use a hint of good news – especially about economic development – it's Bancroft.

Originally built on forestry and mining, the town has watched all the area's mines close down and its forest industry struggle. Nine saw mills still survive around Bancroft, but rising transportation costs and a strong Canadian dollar are nipping at their bottom lines.

Bob, then, would surely be intrigued by news that could suggest a light at the end of the economic tunnel.

A team of researchers at Montreal's Concordia University, I told him, was developing an economical method to convert forest waste into ethanol, that much-sought-after replacement, or at least supplement, for gasoline. The goal was to find a natural agent that would get ethanol out of wood and plant waste in much the same way – and as easily – as yeast gets beer out of hops. Commercial application was only a few years away.

I didn't bother pointing out that Bancroft, with its saw mills, was a contender for the world capital of forest waste. Bob didn't need me to connect the dots. I simply waited for some expression of cautious excitement.

What I got was a long silence and something that sounded like a sigh.

"We've been here a lot of times with a lot of projects," he finally said. "Raising the community's hopes really isn't good." He ticked off a list of proposals and schemes that had seemed like sure things – and then just faded away. "We've heard dreams before. But people need to do their homework, develop a really solid business plan."

I got the same kind of cautious and decidedly un-excited reaction from Jim Clayton, a local businessman and occasional municipal council member who's been working on economic development issues in the area for 20 years.

He told me he'd looked at a proposal for an ethanol plant in the area nine years ago, also based on using forest waste. Several local representatives even got as far as touring what was touted as a prototype facility in Mississippi. "It was more hype than reality," he said. "Not even in operation." Besides, when he'd looked at the demand for ethanol – then very low – the numbers for the Bancroft plant just hadn't added up.

Then he related another telling story about a local proposal for burning forest waste to generate electricity. The business plan was solid and all that was needed to proceed to construction was a burn test at the National Research Council. But a federal election intervened. The government changed hands. The Council's budget was trimmed. The test was delayed. And the funding was lost.

I could almost hear him shrug over the phone. "Sometimes the timing just doesn't work out."

I came away from my two encounters sobered and a little chastened. Yes, scientific advances can be exciting in their own right. But it can be hard going to translate technological buzz into local engagement – especially when the local field of dreams has been burned over a couple of times. In capturing hearts and minds for innovation, hearts can be the most elusive.

Green or Red Light for Ethanol? (FSJ4)

Popular uprisings across North Africa and the Middle East have put energy security on the political agenda just as Canada's new federal ethanol rules come into force. But the complex issues that have sparked political turmoil elsewhere have some Canadians questioning whether ethanol is a fuel fix or future failure.

This past December the Harper government implemented new legislation that requires all gasoline sold in Canada to contain a minimum of five per cent ethanol. The move is part of a federal renewable fuels strategy that includes the ecoEnergy for Biofuels Initiative that will pump up to $1.5 billion over the next decade into subsidizing renewable fuels, primarily ethanol, production.

At present, every drop of ethanol in Canadians' tanks is produced from fermented corn and grains.

"It's not a good idea to rely on ethanol," says John Caldwell, filling his van at a Francis Fuels station in the Ottawa Valley town of Almonte, a half-hour drive from Parliament Hill. "We have people starving in the world who can't afford to feed themselves so that we can drive gas guzzling cars."

He's not alone in this view. One of Canada's top environmental lawyers says that ethanol not only puts pressure on food prices, but is also a green wash when it comes to environmental benefits.

"The bottom line is that the renewable fuels regulation is a better win for the agricultural lobby than it is for those concerned about climate change," says Toronto-based lawyer Dianne Saxe in a recent online blog.

She notes that while the government and Canadian Renewable Fuels Association tout ethanol's lower green-house gas emissions, ethanol contains less energy that gasoline, the regulations will mean that total demand for gasoline will actually increase by 4.4 billion litres over the next 25 years.

"Ethanol has clear environmental benefits only when it is based on waste materials, such as cellulose left over from other processes," says Saxe.

It's this so-called second-generation biofuel approach that has some Montreal-based researchers arguing there's a made-in-Canada solution to the ethanol food versus fuel controversy.

The Concordia University researchers are searching for new fungal enzymes – the same kind that turn compost scraps into soil - than can help turn forest and field wastes, such as branches and straw, into ethanol. The enzymes are used to digest these tough woody fibres and turn them into simple sugars that can be fermented to make ethanol.

“(Researchers) knew before that there were problems with corn-based ethanol,” but there were strong political and economic interests in the US pushing this route, says Concordia biofuels scientist Adrian Tsang.

He says the future of new biofuels can learn from this.

“It’s not all advantages,” Tsang notes. For example, agricultural and forestry wastes could only ever supply a small fraction of biofuel needs, thus creating demand for “energy crops” such as trees and crops from non-agricultural lands.

Ottawa-based Iogen Corporation, which operates the world’s first ethanol-from-straw facility, estimates that it would take one-third of all straw produced in the Prairie provinces to produce ten percent of Canada’s transportation fuel.

Back at the fuel pump, Almonte resident John Caldwell wonders whether there will also be hidden environmental and social costs associated with new biofuels?

Says Concordia’s Tsang: “We won’t really know until this is a widespread practice.”

APPENDIX V: Public participation model-based test stories

Public participation story (FSJ1)

Biofuels aren't quite on the public radar in Canada yet, but at least one group says they ought to be considering the ongoing "food for fuel" debate in the United States.

Touted as a way to run our society on cleaner fuel than traditional gasoline or diesel, biofuels like ethanol can come from many sources, ranging from wheat left over after the crop, to spoiled food.

But their use will raise a whole new set of ethical questions that go beyond whether we are polluting our atmosphere, said a representative from the Pembina Institute, a Canadian policy research group that examines environmental issues like climate change and energy.

"(The fuel) could be coming from your backyard," said Jeremy Moorhouse, a technical analyst at the institute who has a background in mechanical engineering.

"People should be worried about this 'food for fuel' agreement – is your decision to drive a car actually increasing food prices somewhere around the world? That could be another tough decision for people to make."

At Concordia University, researchers are inviting the public in to public lectures to learn how they are breaking down the genomes, or genetic makeup, of about 30 different types of fungi to see what enzymes could be suitable for fuels.

Running your car or furnace takes a chemical "spark" to get the reaction going, and enzymes are the proteins that drive the spark. Researchers at Concordia are working to find the best chemical combinations possible for the fuels.

"A portion of our budget is trying to seek public input – how do we engage the public, how do we get them to know what we're doing, as much as possible," said Adrian Tsang, the director of Concordia's centre for functional and structural genomics.

His group emphasizes that for the type of ethanol they're looking at using, it would be waste to avoid the whole issue of food vs. fuel.

That said, fellow researcher and biochemistry professor Justin Powlowski said they are aware of the growing "food vs. fuel" movement in the United States, particularly when it comes to corn.

The debate hit the public radar in 2007 when then-president George W. Bush encouraged his nation to generate 132 billion litres of biofuels in a decade to wean 15 per cent of American fuel usage off of gasoline.

Publications like Business Week consulted experts who said it would take at least 50 million additional acres of crops to get that kind of return – in a market where the 430 million acres of cropland are already heavily used.

"It's easier to produce ethanol from the starch in the corn because it's relatively pure, in the corn kernel. You can produce glucose quite easily using enzymes from corn," Powlowski said.

That tidal wave of controversy has yet to reach Canada, but when the time comes, the Pembina Institute says it will be on the onus of citizens to get involved.

"There's a whole range of different fuels out there with different benefits and impacts," Moorhouse said.

"We should always be doing sustainability criteria on a case-by-case basis, as there's no guarantee a technology can be used responsibly."

Back to the future: searching for genetic needles in a haystack (FSJ2)

Adrian Tsang's idea of progress would take us back about a hundred years, to a time before our society and our economy revolved around petroleum. We would still have most of the creature comforts that oil and its by-products now provide, but without the need to extract them from a non-renewable source. Instead, biological processes could supply the basic feedstock for our lifestyle — powering engines and manufacturing materials with a much more modest environmental impact. Even our farm animals would eat better, reducing their significant contribution of greenhouse gas emissions associated with climate change.

Tsang, a Concordia University biologist, sees this future emerging from the humble yet crucial activities of the world's fungi. These simple creatures mediate complex arrays of biochemical interactions, displaying an unrivalled ability to digest substances as unlikely as plastics or kerosene.

"These organisms are the major decomposers of terrestrial biomass," he says, noting that we have harnessed this capability to make fermented commodities like bread or alcohol. We can even turn crops such as corn into viable fuels, although replacing all petroleum use in this way would undoubtedly compromise our ability to feed ourselves.

Instead, Tsang proposes working with biomass like straw, which we regard as waste but which appeals to many fungi. They decompose it with enzymes, chemical agents that we already know how to apply to major industrial processes. Fungi, however, clearly know much more.

"They have developed all kinds of strategies to break down the toughest materials," explains Tsang. "They have had a billion years of evolution to handle this. We're basically learning from them."

He has been learning from them for about 20 years, and he now heads an international effort to understand the remarkable biochemical feats of fungi. Tsang is the leader of Genozymes for Bioproducts and Bioprocesses Development, a project that has received more than $17 million in funding from Genome Canada. Based at Concordia, the work includes six partner organizations, including universities, government agencies, and private firms.

At first glance, the goal looks simple enough: identify the complete genetic code of 30 different fungi. That should yield a massive database of proteins and enzymes, which can then be explored to tease out the dynamics of particularly interesting processes. Insights can nevertheless remain elusive, however, as Concordia chemist Justin Powlowski recalls after looking for the genetic secrets behind why some fungi can thrive at temperatures of 60 degree C or more.

“There was almost nothing that we could identify just from the genome sequence that could explain why these things could grow at high temperatures,” he recalls.

Tsang, for his part, acknowledges the complexity of the task, but remains optimistic about the ultimate objective. He points to the discovery that animals like cattle emit large amounts of methane because their digestive tracts lack specific enzymes to digest grain. If the action of these missing enzymes can be identified, they can then be added to cattle feed and the output of this potent greenhouse can be reduced.

“Quite clearly, we are transitioning to a biomass-based economy,” he concludes. “This is how we will reduce our energy requirement, as well as our environmental footprint.”

APPENDIX VI: Focus group guide

1. **Opening question:** Introduction and expectations (10 mins)
    - Could you please just introduce yourself give us a bit of an idea why you wanted to participate in this focus group.

2. **Current news habits** (20 mins)
    - When you read the news, what kind of stories do you usually pay attention to?
    - What about science news stories?
    - What is it about science stories that makes you want to read them or not?

    Probe: Tell us about the last science news story you read. OR What, to you, makes a good science news story? OR What could or should science news stories do to appeal to you more, to get you to read them?

3. **Traditional models (science literacy and contextual stories)** (25 mins)
    - What did you think about them?

    Probe: Was there anything that struck you while reading them? Anything you really liked or really didn't like?

    - Purpose and focus: What do you think were the purposes of these stories? What did they focus on?
    - Style: How did you feel about the style of the stories? Were they enjoyable, effective, understandable, etc.? Why?
    - Sources: Was there, in your mind, anything missing from the story? Was there anything you hoped the journalists would have covered but didn't? What else would you have liked to see in there?
    - Science: What did these stories make you think about the project that scientists working on?
    - Audience: Did the information you read in these stories affect you in your day to day life?

4. **Non-traditional models (lay-expertise and public participation stories)** (25 mins)
   - What did you think about them?

   Probe: Was there anything that struck you while reading them? Anything you really liked or really didn't like?

   - Purpose and focus: What do you think were the purposes of these stories? What did they focus on?
   - Style: How did you feel about the style of the stories? Were they enjoyable, effective, understandable, etc.? Why?
   - Sources: Was there, in your mind, anything missing from the story? Was there anything you hoped the journalists would have covered but didn't? What else would you have liked to see in there?
   - Science: What did these stories make you think about the project that scientists working on?
   - Audience: Did the information you read in these stories affect you in your day to day life?

5. **Final comments** (10 mins)
   - In a few words, can you wrap up/summarize what the main points were for you today? Now is also the time to raise anything that you'd like to talk about but hasn't been addressed yet.