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Comparing science communication theory with participatory practice: case study of the Australian Climate Champion Program

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Abstract

While short-term participatory science communication activities have been well researched, long-term programs have received scant attention. Analysing survey data and participant discussions, I investigated interactions between Australian farmers and scientists engaged in the Climate Champion Program (2009–2016). I compared their interactions to three theorised science communication models: deficit, dialogue and participatory. I found their interactions illustrated a mix of the characteristics of all three models. While farmers and scientists appeared to be motivated to interact by deficit and dialogue objectives, respectful and trusting relationships emerged from long-term participation, which was key to making deficit- and dialogue-style communication more effective.

Keywords Participation and science governance; Public engagement with science and technology; Science communication: theory and models

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Context

In response to calls for more deliberative and open engagement of publics in controversial scientific issues, participatory science communication activities have emerged — including consensus conferences and citizen juries [Nisbet and Scheufele, 2009; Allen, 2018]. Bucchi and Neresini [2008] describe the characteristics and duration of some of these activities. Most of these activities, such as referenda, hearings and inquiries, occur over a short period of time (within a day or over several days), except for negotiated rulemaking, in which a working committee of stakeholders may last days to months as they seek consensus on specific questions. There has been significant research on some of these short-term participatory science communication practices. For example, consensus conferences on controversial topics like food biotechnology [Edna F. Einsiedel and Breck, 2001], nanotechnology [Kleinman, Delborne and Anderson, 2009] or citizens juries, such as United Kingdom's (U.K.) NanoJury examining nanotechnology and its implications [Bickerstaff et al., 2010]. However, there has been little research about longer term participatory science communication projects.

In this paper, I investigate a long-term participatory science communication initiative conducted in Australia over seven years (2009–16), the Climate Champion Program (CCP). The CCP purposively created opportunities for scientists and selected farmers to engage with each other directly and openly to better understand and manage climate risk. Climate change is a controversial public issue in Australia, as it is in many countries around the world. Despite scientists warning Australians about climate change threats over 30 years ago, Australia is ranked among the worst of the developed countries for climate action [Burck et al., 2019].

1.1 Defining participatory science communication

'Participatory science communication' emerged as an umbrella concept and area of interest for a range of science engagement activities, including citizen science [Irwin, 1995], consensus conferences [Guston, 1999], and citizen juries [Haklay, 2013]. Such activities cover a range of various of means of citizens participating with scientists from collecting data to "collaborative shaping of research questions and methods" [Allen, 2018, p. 950].

In this paper, I define participatory science communication as a means by which scientists interact with specific public/s, which may be referred to as the 'concerned group', where relationships between various participants are contested and negotiated over a period of time [Callon, 1999; Elam and Bertilsson, 2003; Hagendijk and Irwin, 2006]. The objective of such participatory science communication is to explore questions of mutual interest, and in so doing create new knowledge and/or new means of dealing with a specific problem. Scientists do not necessarily drive the participative process and publics may initiate and direct the engagement.

1.2 Theorised participatory science communication models

In the early 2000s, a new participatory model of science communication gained traction in the scholarly literature. The participatory model appealed to scholars who saw the potential for the democratisation of science as a solution to engaging publics in jointly tackling societal issues of concern [Brossard and Lewenstein, 2010; Bubela et al., 2009; Joly and Kaufmann, 2008; Miller, Fahy and the ESConet Team, 2009]. These scholars saw that more public participation in science may open its processes and governance up to more direct public scrutiny, hence making it more democratic. For controversial scientific issues, like climate change, public participation was argued to be beneficial for critically reviewing research, solving problems, or supporting behaviour and policy changes [Few, Brown and Tompkins, 2007; Höppner, 2009; Marquart-Pyatt et al., 2011].

Scholars [Mohr and Raman, 2012; Stirling, 2008] theorise three different motivations for participatory engagement of the public in and with science: *normative*, because the process of participation is the 'right thing' to do; *instrumental*, where the specific outcomes of the participation are more important than the process; and *substantive*, where outcomes are negotiated and designed by all parties involved in the participative process. Trench [2008] sees participatory communication as a combination of the normative and the substantive when he says it is as much about the process of engagement as about the outcomes, and that it, “takes place between diverse groups on the basis that all can contribute, and that all have a stake in the outcome of the deliberations and discussions” [p. 131]. The normative and substantive participatory models signal a more obvious shift in power than the instrumental model — from the scientists to publics.

Scholars theorise that with participatory science communication activities, scientific knowledge is just one of the many sets of knowledge brought to the engagement process, along with knowledge from various concerned citizens, sectional interests, and non-government organisations [Callon, 1999; Palmer and Schibeci, 2012; Pouliot, 2009; Rowe and Frewer, 2005]. To go further, some scholars have called for publics to have more influence over what science actually gets done or not in the first place [Rogers-Hayden and Pidgeon, 2008; Wilsdon and Willis, 2004]. Others have postulated that participatory activities need to move ‘upstream’ beyond consultation and participation to co-creation of science and technologies [Rogers-Hayden and Pidgeon, 2008].

These participatory approaches are usually contrasted in the literature with the theorised deficit (one-way communication from scientists to public) and dialogue (two-way communication between scientists and publics) models of science communication, as shown in Table 1. The differing characteristics of the three main models of science communication according to the literature are summarised in Table 1.

While a prevailing notion in the science communication literature is one of distinct and evolving science communication models [e.g., Höppner, 2009; Palmer and Schibeci, 2012; Stocklmayer, 2013], a growing number of scholars argue that science communication models coexist in practice rather than occur as a linear progression [e.g. Brossard and Lewenstein, 2010; Bucchi, 2008; Jensen and Holliman, 2016; Metcalfe, 2019; Trench, 2008]. However, there has been little further theoretical consideration of how such findings in practice might shape or evolve new understandings or models of science engagement.

Theorised science communication models attempt to capture a past, present or possible reality; but the assumptions of these models have not been widely tested with reference to the practice of science communication [Salmon, Priestley and Goven, 2017]. One notable exception to this was Brossard and Lewenstein’s [2010] analysis of the Human Genome Project’s Ethical, Legal and Social Implications outreach. In this study, case studies of practice were compared with four science communication models: deficit, contextual (where scientists consult the public to understand how people respond to information and thus communicate better with them), lay expertise (where scientists seek to understand and value lay knowledge alongside scientific), and public engagement (where citizen views and knowledge are integrated into policy debates). Brossard and Lewenstein [2010] found that, in practice, projects took a pragmatic approach and adopted parts of each science communication model according to the different contexts and needs of various publics.

Table 1. Comparison of selected characteristics of theorised deficit, dialogue and participatory models of science communication [Brossard and Lewenstein, 2010; Bucchi, 2008; Callon, 1999; Durant, 1999; Irwin, 2008; Kurath and Gisler, 2009; Miller, 2001; Palmer and Schibeci, 2012; Pouliot, 2009; Rowe and Frewer, 2005; Scheufele, 2014; Stocklmayer, 2013; Trench and Junker, 2001].

Characteristic	**Deficit**	**Dialogue**	**Participatory**
Objectives	1. Raise awareness of science 2. Inform about science 3. Correct misconceptions 4. Gain support and funding for science 5. Promote careers in science 6. Popularise science 7. Educate in science 8. Address concerns about science 9. Improve decision-making through increased knowledge 10. Respond to interest in science 11. Change behaviours and attitudes	1. Address mistrust in science 2. Discover public opinion about science and thus communicate more effectively 3. Gain and use lay knowledge 4. Debate/discuss scientific issues 5. Connect with those from other disciplines 6. Be more accessible and accountable to public 7. Engage public in decision-making	1. Collectively learn 2. Jointly produce new knowledge 3. Jointly solve a problem 4. Participate with public in policy making 5. Participate with cultural interests other than science 6. Shape the research agenda 7. Critically reflect on science
Actors	Scientists, science communicators, public	Scientists, science and government institutions, science communicators, public	Depends on scientific issue to be explored but usually multiple actors
Nature of interaction	One-way, top-down	Two-way	In multiple directions between multiple actors
Relationship between actors	Scientists have control	Scientific and government organisations have control, but wish to consult or converse	Equal and shared, and based on trust
Knowledge	Scientists have all the necessary knowledge	Scientists have the most important knowledge, but they can gain new knowledge from others	There are multiple sources of knowledge and expertise of equal worth and validity
Acknowledgment of risk	Science portrayed as certain	Risks acknowledged as levels of uncertainty in scientific knowledge	Risk related to the social contexts and values

Jensen and Holliman [2016] investigated practices and discourses of U.K. scientists at various stages of their careers who engage with the public about their own experiences, and compared these to Irwin's [2008] three levels of thinking. Irwin's first-level thinking is similar to the deficit model (where scientists convey information to publics using one-way communication methods); the second-level thinking is similar to the dialogue model (where scientists engage with publics through a two-way conversation); and the third level of thinking (where scientists engage directly with publics on a more equal basis) towards a more critical engagement of publics in science and its institutions. Jensen and Holliman [2016] found the experiences of practitioners to be firmly rooted in deficit-style communication, with some limited discourse about and acceptance of dialogue methods. There appeared to be very little experience of second- or third-order thinking activities. However, this study did not examine specific science communication practices but rather the perceptions of the science communication practitioners.

1.3 The Climate Champion Program (CCP) case study

The CCP offers a good case study of a long-term science communication initiative that was deliberately participatory, involving scientists, farmers and research managers. The CCP was an initiative of the national Managing Climate Variability (MCV) research and development program and Grains Research and Development Corporation (GRDC) communication strategies.

The focus of MCV's research, and to some extent the GRDC-funded research, was to provide farmers with better seasonal climate forecasting tools to manage their climate risk. Seasonal forecasts use scientific models to predict the climate for the coming months. Seasonal climate forecasts have the potential to improve farm profitability, minimise land degradation, assist with drought preparedness and reduce vulnerability to future climate change [Hansen et al., 2006]. However, the challenge of communicating seasonal forecasts stems from the probabilistic nature of such forecasts, which means they include a degree of uncertainty and can be complex to understand. A 2008 MCV online survey of farmers' needs from seasonal forecasts asked for feedback on some of the Australian Bureau of Meteorology's draft seasonal forecasting products. This study [Land and Water Australia, 2008] found there was a need for MCV and the Bureau to "work with target users, in a participatory style of science communication" [p. 25] to help jointly develop clearer explanations of climate risk and the terms used to explain that risk. It was this recommendation, along with research indicating that farmers best learn from other farmers [Jacobi, Crump and Lundquist, 2011; Patel et al., n.d.], that drove the development of the CCP initiative.

The instrumental goal of the CCP was to support leading farmers across Australia, to communicate with their peers about climate science and the means for adapting to and managing climate risk. As such, the CCP illustrates a sponsored participatory program [Bucchi and Neresini, 2008]. However, individual scientists and farmers initiated and negotiated their own activities in similar ways to activities occurring in unsponsored programs. This was demonstrated at the first workshop in March 2010, where CCP farmers were encouraged and supported by the science communicators organising and supporting the program to set their own objectives and design their own activities, including how they wanted to engage with scientists.

Over the seven years of the program, 45 Australian farmers participated from all states and territories in Australia except for the Northern Territory. Farmers represented a range of enterprises, including beekeeping, grains, dairy, beef, fine wool, sugar, cotton, viticulture and horticulture. A mix of scientists participated in the program, including climate, agronomic and social scientists. There was a core group of 12 scientists who participated throughout the seven years. CCP farmers met with the scientists in face-to-face formal workshops, informal farm visits, and through the initiatives of individual farmers and scientists.

My study focuses on interactions between farmers and scientists within the program rather than farmers communicating with other farmers outside of the program.

1.4 Research question

This paper examines the characteristics of the CCP, as reported by participants in online surveys and by analysing the dialogue at a workshop, against the theorised characteristics for deficit, dialogue and participatory models (summarised in Table 1). My research investigates the question: to what extent are the theorised characteristics of the three models of science communication reflected in the CCP?

Methods and analysis

2.1 Surveys of participants

In the last month of the CCP (June 2016), the organisers asked all the CCP farmers (n = 45) who had been involved in the program over the seven years and the scientists who had been actively involved throughout (n = 12) to complete a short online survey (see appendix A). Responses were collected from 32 CCP farmers and eight scientists. All participants agreed to be identified and to have their responses included as part of this research. This study received ethics approval through the University of Queensland.

I analysed four similar open-ended questions for each of the surveys:

1. Whether they had done anything different because of the CCP
2. Whether the project had resulted in any personal benefits
3. Whether the project had resulted in any benefits for Australia
4. What could be improved about the project?

I used a template analysis approach [King, 2004; Huberman and B., 1994] where the data collected from the four questions was thematically organised and empirically compared to the characteristics identified in theoretical perspectives (summarised in Table 1) for the deficit, dialogue and participatory models of science communication.

None of the four questions explicitly asked the participants' objectives for participating in the program. However, their perceptions of the benefits of the program provides at least some indication of what they hoped the program would achieve as well as what they valued from the program. For example, if a farmer says a benefit of the program is giving them confidence and skills to raise awareness with other farmers about climate risk, then I deduced that this was something they valued about the program.

The surveys' other quantitative questions provided more direct measures of characteristics, such as the nature of interaction and relationships between actors.

2.2 Workshop discussions

I analysed six transcripts of independently facilitated discussions from a 2014 workshop involving CCP participants, which were held after formal presentations by scientists about climate risks. The discussions involved 11 scientists and 13 farmers.

I thematically analysed the workshop transcripts to identify the nature of participation and the kinds of relationships developing between farmers and scientists involved in the facilitated discussions.

My thematic analysis was guided by the four overall modes of participation identified by Kouper [2010] . The first mode of participation is indicative of dialogue- or participatory-style communication, while the last three modes demonstrate more deficit-style communication.

1. Contributing to the topic — e.g., reporting from an external report or source, making an argument that adds to the topic, explaining more about the topic or asking questions of clarification
2. Deviating from the topic — e.g., digressing, insulting, self-promotion
3. Expressing attitudes or emotions — e.g., approval, disapproval, regret, personal experiences, anger
4. Attempting to influence others' actions — e.g., through advice, recommendations, requests, and proposals.

I analysed all comments, and each comment could have more than one mode of participation. My analysis focused on trends and examples of trends rather than quantifying how often the four modes occurred. I also separately reviewed the discussions to ascertain how the participants were constructing (jointly or separately) the nature of risk associated with the climate science they discussed.

Results

3.1 Actors' perceptions of the benefits of participation

My analysis of the survey's qualitative questions revealed what they valued about the program, which is some indication of their possible objectives for being involved in the program. As Table 2 shows, both farmers and scientists valued a mix of possible objectives across those predicted for all three models. However, there was less perceived benefit for some of the predicted participatory model objectives (e.g., joint problem-solving, participation in policymaking) and more focus on deficit objectives such as improving decision-making through increased knowledge and changing behaviours and attitudes.

The most frequent participatory-style objective identified in farmers' contributions was to 'collectively learn'. A typical statement in response to the question about what farmers liked best about the program was, for example:

Interaction with fellow farmers and top researchers about the effects of climate change and how best to manage and mitigate that without the negativity of local ill-informed views" (FS03 — code for a farmer who responded to the survey, who was labelled number 3).

Table 2. The objectives of CCP farmers and scientists that emerged from survey qualitative data compared to those predicted by theorised science communication models, as summarised in Metcalfe [2019, p. 385–386]. (X = mentioned by a few participants; XX = mentioned by most participants; XXX = mentioned by almost all participants).

Objectives characterised by models	Farmers	Scientists
Deficit		
Raise awareness of science	XXX	X
Inform about science	XX	XXX
Correct misconceptions	X	XX
Gain support and funding for science		X
Promote careers in science		
Popularise science		
Educate in science	X	XX
Address concerns about science	X	X
Improve decision-making through increased knowledge	XXX	XXX
Respond to interest in science		XX
Change behaviours and attitudes	XXX	XXX
Dialogue		
Address mistrust in science		X
Discover public opinion about science to communicate more effectively	XX	XXX
Gain and use lay knowledge	XX	XXX
Debate/discuss scientific issues	XXX	XX
Connect with those from other disciplines/areas	XX	X
Be more accessible and accountable to public	XX	XX
Engage public in decision-making		
Participatory		
Collectively learn	XXX	XX
Jointly produce new knowledge	XX	X
Jointly solve a problem	X	X
Participate with public in policy making		
Participate with cultural interests other than science		
Shape the research agenda	XX	XX
Critically reflect on science		

Another perceived benefit from the program, described by about a third of CCP farmers, was that it increased the profile and importance of climate to their peers and the wider community. For example, as one farmer said, "I consider it was starting to make a real impact — I was seeing graziers [cattle and sheep farmers] at workshops discussing climate change who would never have come previously" (FS07). Another said:

Helped raise the profile of climate change, with consistent clear and factual messaging. Assisted the uptake of information and tools to use forecasting and adaption tools to manage variability (FS28).

Some farmers indicated that engaging with scientists helped them establish their own credibility in the climate space, for example, "Putting climate on the table and giving credibility to agriculturalists as voices for climate" (FS01).

Another benefit that many of the farmers thought they got from the CCP was participating with each other even though they were working in different industries in various locations across Australia. For example:

> The most beneficial experience for me was learning from other farmers about how they are responding to climate risk, about their communication strategies and successes, and about their ways of negotiating information (FS19).

This reflects dialogue objectives of gaining lay knowledge and connecting with those from other disciplines/areas.

The scientists involved in the CCP valued the direct access the CCP gave them to representatives of agricultural industries across Australia; the feedback they received about their research, their draft products and tools, and the way feedback was communicated; and interacting with a knowledgeable and willing group of farmers. Their apparent objectives, as derived from what they valued about the program, also spanned those predicted by the three science communication models (see Table 2). Like the responses of farmers, what they valued about the program most strongly reflected those predicted for the deficit and dialogue models. They particularly valued the opportunity to interact and discuss their research with farmers, which was often framed in the context of using the group for some specific purpose (see objective 3 under dialogue in Table 2). For example, "As co-ordinator of a national CC [climate change] Adaptation network it provided me with an extremely valuable industry-based network to tap into when we wished to interact with their particular industries" (S02).

3.2 Nature of interaction

In response to the quantitative survey questions, most CCP farmers reported a moderate to high interaction with scientists over the course of the CCP. The more years that CCP farmers were involved in the program, the higher their interaction and activity. When asked if there were enough opportunities to interact with scientists the majority (n = 26) said 'just right', with only six reporting 'too little'. Four people stating that they had 'too little' interaction had been involved in the program fewer than four years. No farmer reported too much interaction.

The scientists' highest level of interaction occurred through organised workshops, either presenting to CCP farmers or discussing their research with them at these forums. These reported interactions align with those predicted for deficit and dialogue models, rather than participation.

The analysis of the 2014 workshop discussion sessions between CCP farmers and scientists indicate that farmers and scientists were contributing to dialogue by explaining, describing or questioning in relation to specific topics. There was minimal deviation from the focus topics being discussed, and when there was, it was a slight digression with no hint of participants being insulting or self-promoting. Farmers were more likely than scientists to express an attitude in their comments. Such comments usually related to their personal experiences on their farms, and what this meant for them. For example, the following workshop discussion comment from CCP farmer coded FW03 (farmer involved in the workshop, coded as 03) is typical:

> The tools, we are using more and more in terms of [finding out about] soil moisture, type of soil we've got. . . But at what point do you stop getting more info? Takes a lot to stop. What are your options if you choose to do something if the forecasts tell you not to? We have a lot of [water] entitlements in our area — at what point do I start to sell our water? Sometimes you have to be brave to make the right decisions — some farmers get caught up in love of farming sometimes, so they don't manage their risk really well.

Scientists, on the other hand, made more statements than farmers that indicated a desire to influence others. For example, the following statement from scientist SW12 (scientist at the workshop, coded as number 12) talking about seasonal forecasts and nitrogen management:

> I think we need to be more realistic about some of the other limiting factors — established population, stage of crop — and maybe apply less N [nitrogen] and still produce the same crop, but that's where we'll have a big impact with reducing emissions.

However, none of the scientists' comments indicated they were motivated to tell farmers what they absolutely should do. Instead, scientists appeared to be actively listening and asking questions, as demonstrated by the following exchange between one scientist (SW07) and CCP farmer (FW05).

> (FW05): Can I just relate my experience last year? So, very wet winter. Our subsoil is chock-a-block full [of water]. So, the three-month forecast says spring is going to be above average [rainfall]. So, I trotted off to the bank manager and said, 'if ever I'm going to put nitrogen on, it's going to be this year'. And he reluctantly lent me the money. And by the time I had the urea in the shed the forecasters came out and said that 'we have changed our mind on the spring forecasts, and it might not be as good as what we had first thought'. So, I put out a small amount of urea. I barely got it incorporated and, in the end, I might have got my money back, I might have had a small loss, but that's the sort of decision-making you have to put up with all the way through. If we could get more accurate forecasts, particularly weekly and multi-week forecasts, that would make a huge difference, rather than having that big gap that we were talking about before.
>
> (SW07): So [FW05], you're making this decision in August?
>
> (FW05): Yes. Well, say July, mid-July.
>
> (SW07): You're ordering fertiliser in July. And you're putting it out in August?
>
> (SW07): So, you're in a very dry environment. So, there are plenty of people south of you who will be doing this as well?
>
> (FW05): Very much so. This is a one in 10-year opportunity that I thought had presented itself.

> (SW07): So, you would be after a six-week forecast? So, in that July-August period you are really interested in what is happening in the next 6 weeks?
>
> (FW05): Exactly, and you are assessing the probabilities of success, and that sort of stuff. But it all comes back to this accuracy. The accuracy is really paramount because you are really sticking your neck out for this quite often.

The dialogue between farmers and scientists appeared genuine, with each taking turns to listen to each other, and openly express their views without criticism. Farmers shared their experiences as a way of influencing scientists, and scientists used their knowledge to influence farmers' actions.

3.3 Relationships between actors

The survey included two quantitative questions which assessed how willing farmers and scientists were to listen and respond to each other, which is indicative of the quality of the relationships between CCP farmers and scientists as perceived by each group. Regardless of the length of time in the program, the CCP farmers rated scientists very highly for both their willingness to listen (average of 4.3 where 1 is not at all and 5 is very willing), and their responsiveness to questions asked of them (4.2/5). The scientists who responded to the survey also rated the CCP farmers' willingness to listen (4.9/5) and responsiveness to their queries (4.5/5) very highly.

The nature of the perceived relationships between farmers and scientists, as analysed in the open-ended questions, was found to be generally positive, with several participants saying their relationships with their counterparts in the program had turned into friendships. For example, a climate scientist from the Bureau of Meteorology (SS06 — scientist responding to survey coded as number 06) said his highlight from interacting with CCP farmers was "Meeting the real users of our BOM [Bureau of Meteorology] products — hearing how they used it and what they would like to see from our work. But also, friendships made". Likewise, several CCP farmers noted friendships formed through the program as a highlight: "The friendships formed and the understanding of issues right across Australia" (FS24).

Scientists responding to the 2016 survey rated their satisfaction with participating in the program very highly (average of 4.4 where 1 is very low and 5 is very high). When asked how the program could have been improved, both CCP farmers and scientists recommended even more participation between farmers and scientists.

Analysis of the discussion sessions at the 2014 workshop indicates that scientists and farmers have developed relationships of mutual trust where they feel they can be open with each other and critically reflect on what is happening in science and in agriculture. For example, in the final discussion session, a farmer (F11) asks the scientists what the impediments are for achieving multi-model forecasting. A scientist (S2) responds by acknowledging a lack of organisational will: "I think there is preparedness among many in the science community to work together. The ability to do that is frankly associated with the ability of their institutions to work together". This reflects the sort of open and equal relationships typical of the participatory science communication model.

3.4 *Knowledge*

When CCP farmers were asked about the quality of information presented to them by scientists, they rated the importance of quality very highly (average of 4.2 where 1 is very low and 5 is very high). Likewise, when scientists were asked to rate the quality of feedback they received from CCP farmers, they rated the importance of this highly (average of 4.1 where 1 is very low and 5 is very high).

The survey's open-ended responses showed how reciprocal knowledge was valued and used by farmers and scientists. One-quarter of CCP farmer respondents explicitly stated that their understanding of the climate science was improved through their engagement with CCP scientists. For example, when asked if they had done anything different because of their participation, a typical response was "Better understanding of forecasts, how they work and how to use them" (FS07). Others made reference to their use of the presented climate tools: "I use POAMA [seasonal forecasting model] & other climate forecasting tools daily in my business" (FS06). Several CCP farmers thought the program and their interaction with scientists created credibility for their own knowledge: "It gave me some detailed knowledge when discussing climate change with my peers therefore giving my discussions greater credibility" (FS16).

From the survey data, I grouped themes associated with how scientists perceived the CCP had affected them into four outcomes.

1. greater understanding of farmer needs
2. help to shape research tools and products
3. influence on future research
4. improved communication skills.

These outcomes indicate how scientists' improved knowledge of farmers and their situations has changed how they operate.

Firstly, most respondents noted that they now had a much greater understanding of farmer needs. For example:

> Terrific to see how the champs [CCP farmers] helped researchers or policy people better understand the needs of farmers. This was a great improvement to have willing and accessible champion farmers who were across climate issues but offered practical insights for what would be useful for them and other farmers (SS07).

Secondly, the scientists thought that the CCP farmers' feedback helped to shape their research tools and products. For example (SS06), "I altered the presentation/design of some of our experimental forecast products".

Thirdly, scientists recognised that CCP farmers' input helped to shape their research, for example, "My work on linking probabilities to decision-making was encouraged and shaped through the interaction with the group" (SS01). Scientists also noted that their own communication improved because of their participation with CCP farmers:

> It has helped me improve the way I communicate to stakeholders... It has underscored to me the importance of good communication in terms of the uptake and utility of forecast products. Feedback from the workshops has helped us to tailor our development of experimental forecast products, including the presentation of the product (SS06).

A scientist attending the 2014 workshop (SW07) reflected on the themes of the first two days of the workshop. He uses inclusive language, and his statements indicate that scientists and farmers have learnt from each other over the course of the workshop:

> I'm hearing a lot of common themes...One is that there is a lot of information already available that not everyone knows about and knows how to interpret properly. So, I think it's important to find a mechanism where we can get the information out not just to you guys but to all farmers to explain the information that is not misleading but useful...The other theme I'm hearing a lot is the need for information at smaller scales than POAMA is providing. And I think that is an issue we have to deal with. How do we do the downscaling with the model that we've got? Whether it is 250km or 75km in a few years; it's still not at your farm gate. So, I think we have to think about how we downscale the information.

As this quote illustrates, participants in the CCP respect each other's knowledge and see it as equally valid in jointly solving climate risk problems. However, scientific knowledge is still perceived as separate from the farmer's lay knowledge. Farmers and scientists did not indicate that they were co-jointly developing new knowledge to manage climate risks.

3.5 Acknowledgment of risk

The scientists surveyed acknowledged that their participation with CCP farmers helped them to better understand the nature of the climate risks farmers face. One scientist said his conversations with the farmers reinforced the need to further examine climate risks as they relate to on-farm practice:

> Most recent was around the balance of focus on managing seasonal and climate risk on farms. Need not only better forecasts, but better farmer literacy of climate for their region, and then the tools/tactics/ strategies to manage whatever happens (SS08).

Better knowledge of how to manage climate risk was articulated by scientists as a specific benefit of the program, for example, "A step towards helping a shift in industry attitude towards climate change/variability and individual ability to respond proactively with risk management" (SS03). Climate risk was an overriding theme of the CCP and both scientists and farmers were open about the risks when interpreting research, and what that meant for managing risk within a farming enterprise.

Scientists participating in the 2014 workshop discussions did not hesitate to articulate areas of uncertainty, demonstrating that they had developed trust in CCP farmers' ability to interpret such uncertainty and respond appropriately. For example, one scientist said:

> Last month I went to the first scientific conference focused on multi-week prediction. . . So, it is a really new field and a lot of the work we are doing is pioneering and it's a really difficult time to provide skilful forecasting. The point I wanted to make is that these climate models can produce a whole lot of data and we could give you day-to-day data for the next month but that doesn't mean you should trust it (SW10).

This again demonstrates an openness between participants that some scholars [Bucchi, 2008; Irwin, 2008] thought to be necessary for the participatory model.

Both scientists and farmers recognised that decision-making about climate risk occurred within the economic and social contexts that each farmer faces. For example, in a discussion about how to communicate frost risk to farmers, a scientist (SW04) replied "I think the only successful way to do that is to have farmer workshops. And so, having this regionalised, having the information in a relevant context for the farmers in the room". As such, this reflects the theorised participatory model, at least in terms of addressing the specific contextual challenges that farmers face in dealing with climate risk.

Discussion

The Climate Champion program clearly reflects a mix of the characteristics theorised for the three science communication models. But more importantly, it shows that participatory science communication is likely to result in more effective deficit- and dialogue-style communication. This happens through relationships of trust that develop between participants over a longer time period than just a few days.

The study has obvious limitations: it is one case study of a long-term participatory science communication program in one country. It also involved participation of those who were already engaged in the issues. However, it does provide insights for researchers looking to further develop science communication models and it does indicate to practitioners the importance of science communication programs that foster positive relationships between scientists and publics.

4.1 *Climate Champion Program reflects a mix of theorised characteristics of all three science communication models*

My analysis of the CCP indicates a mix and overlap of the theorised characteristics predicted for the three science communication models. Scientists want to inform farmers of their science and increase farmers' climate science literacy. Farmers are demanding specific information from scientists, and the scientists participating in the CCP are willingly responding. Both scientists and farmers want to improve decision-making (their own and others) through improved knowledge. They want to gain knowledge from each other, and to jointly discuss scientific issues. These are all characteristics of deficit- and dialogue-style science communication.

In support of the predicted characteristics of the participatory science communication model, scientists and farmers want to collectively learn about how to manage climate risk on farms. They also expressed a desire for the research agenda to be shaped with input from all parties. As such, upstream participation of CCP farmers in research appeared — from scientists' responses to the surveys — to have resulted in real changes to the direction and application of climate science. Scientists involved in CCP have modified their research, changed how they have packaged the products of such research, and improved the way they communicate about their research and its products, based on feedback and advice from the CCP farmers. However, there appears to have been less desire by all participants, or possibly opportunity, to jointly produce new knowledge or solve problems, as predicted in the theorised participatory model of science communication. This may be because knowledge was still framed as either science or lay in nature [Kurath and Gisler, 2009].

Through their participation in the program, CCP farmers report that they have gained considerable confidence and improved their climate risk knowledge. Many felt more confident and credible to discuss climate science with their peers. The CCP built the capacity of farmers, which reflects recent engagement research pointing to the importance of such activities for participatory science communication [e.g. Guston, 2014; Selin et al., 2016]

The role of being a 'speaker' in the CCP was usually given to scientists rather than to the farmers, which has also been found in other research on participatory science communication initiatives [Kurath and Gisler, 2009]. However, despite this, there appeared to be critical scrutiny by the CCP farmers of the presented scientific research and its products, unlike the concerns noted by other researchers about this not happening [e.g., Hagendijk and Irwin, 2006; Kurath and Gisler, 2009]. This scrutiny did lead to instances of scientists changing their research direction, and how they packaged and communicated about their research outputs.

4.2 Respectful, trusting and open relationships result from long-term participation

An important finding of my analysis was that participation in the CCP over a significant period of time resulted in respectful, trusting and open relationships between farmers and scientists. Farmers and scientists valued each other's knowledge, there was a perceived mutual benefit from listening to and learning from each other, and they enjoyed interacting with each other. Both groups were prepared to be open with each other and to frankly discuss scientific and specific on-farm uncertainties. Such openness indicates trust had developed between farmers and scientists participating in the program. While open and equal relationships of trust are predicted by theorised participatory science communication models (see Table 1), there is little discussion on the nature of or importance of trust in science communication models, and this is something that should be explored further in future research.

The type of trust developed in the CCP between farmers and scientists is interpersonal, and very much based on relationships [Siegrist, 2010]. Marquart, O'Keefe and Gunther [1995] surveyed 500 dairy farmers about their perceptions of risks of using hormones on their farms. They found that the expertise of those people communicating with farmers did not affect their perceptions of trustworthiness, although attitude similarity does. Perhaps through their participation, CCP farmers were developing similar attitudes to each other and to the scientists, as reflected in their enjoyment of interacting with "like-minded people". Six different farmers used the phrase 'like-minded' when referring to participation within the group, for example, "Interaction with like-minded farmers and sharing our knowledge and experiences in regard to the changing climate" (F16). Carolan [2006] studied the rise of sustainable agricultural with Iowa farmers and postulates 'the local' concept, where networks of trust and knowledge are continuously used, adapted and negotiated. Regular face-to-face, phone and email interactions between CCP farmers and scientists means there was likely a regular renegotiation and deepening of trust based on individual actions and speech. When Carolan [2006, p. 331] examined farmer field days, he found that knowledge was not the only thing being:

> ...conveyed and nurtured at these field days; so too was trust. This trust was not the inactive, passive, "as-if" variety, however. Rather, it was an active trust, built upon the sustained intimacy of social networks and those individuals embedded within those networks.

The interaction between the farmers and scientists in the CCP at workshops and associated farmer field days appears to have created a similar trust between program participants.

4.3 *Participatory communication results in more effective deficit- and dialogue-style communication*

Significantly, trust built through participation means people are more likely to trust and apply the information and knowledge they get from their trusted sources [Carolan, 2006; Hujala and Tikkanen, 2008]. In this context, deficit-style communication is likely to be more effective if it happens between people who have developed relationships through participatory-style science communication. The relationships of trust that developed through participation in CCP may be the main reason why the deficit- and dialogue-style communication was perceived by both farmers and scientists to be so effective: generating a higher profile for climate change; delivering consistent and clear messages; changing research design, products and communication; and increasing adoption by farmers of seasonal forecasting tools.

4.4 *Towards more robust science communication models*

For the CCP, communication that built trust and enabled a participatory approach allowed for more effective knowledge dissemination and dialogue between scientists and farmers. This finding raises the question about how science communication models have been thought to evolve. Generally, the movement of deficit to dialogue to participation is perceived only to be one of progress, but what if real progress happens when participatory communication opens possibilities for more effective deficit- and dialogue-style communication? Rather than deploring the deficit and dialogue models for their limitations and failings, scholars would benefit by examining the contexts in which such linear communication approaches are effective, and even requested or required by the actors involved in science communication.

The CCP demonstrates the likely need for a mix of communication styles and activities in participatory science communication programs. As such, scholars should consider how participatory models of science communication could support and incorporate rather than entirely discard linear communication models. Further, my analysis indicates the foundational importance of the actors in participatory science communication initiatives developing relationships of trust over time. Theorists might consider how to model the benefits derived from developing genuinely open, trusting and respectful relationships, especially when the science is publicly contested.

Concluding remarks

Research that compares science communication theory and practice is essential to pursue if we are to develop our science communication theories and models further through empirical evidence. Such research is also likely to better inform practitioners of the approaches and strategies they might apply to science communication designed to create positive change.

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Selected questions from the Climate Champion Program 2016 surveys of scientists and farmers

A.1 Scientists' survey

1. Please rate your involvement with the following Climate Champion Program activities from 1 (no involvement) to 5 (very high involvement):
   - Presenting at Climate Champion workshops
   - Discussing my research at Climate Champion workshops
   - Requesting feedback to draft research tools or products from Climate Champions
   - Asking Climate Champions to input into my research
   - Responding to Climate Champion queries
   - Inviting Climate Champions to participate/present at conferences or workshops

  - Informal interactions with Climate Champion participants
  - Other (Please describe)
  - Other (please describe)

2. How satisfied were you with your involvement in the program? Please rate from 1 (not at all) to 5 (very high)
3. Please explain your answer to Q2
4. How would you rate the quality of any feedback you received from Climate Champions? Rate from 1 (poor) to 5 (very high).
5. How willing do you think Climate Champions were to listen to your ideas? Rate from 1 (not at all) to 5 (very willing) Also allow a not applicable button.
6. How responsive do you think Climate Champions were to any questions you asked of them? Rate from 1 (not at all) to 5 (very responsive)
7. Did or do you do anything differently because of your interactions with Climate Champions? If so, please describe
8. Did any of the Climate Champions do anything differently because of your interactions with them? If so, please describe
9. What was the best single thing about the Climate Champion Program for you personally?
10. What do you believe was the best single thing about the Climate Champion Program for Australia?
11. Do you have any suggestions for how it could have been improved?

A.2 Climate Champion farmers' survey

1. When did you join the program? Please tick one answer only
   - Financial year 2009–2010
   - Financial year 2010–2011
   - Financial year 2011–2012
   - Financial year 2012–2013
   - Financial year 2013–2014
   - Financial year 2014–2015
   - Financial year 2015–2016
2. When did or will your formal involvement in the program end?
   - June 30, 2013
   - By June 30, 2016
3. One of the objectives of the program was to help develop your skills to communicate with other farmers and industry. How significant was the program in improving your communication skills? Rate from 1 (none) to 5 (very significant) your improvement in the following communication skills as a result of the Climate Champion Program.

4. How much did you interact with climate researchers during the program? Rate from 1 (none) to 5 (Very High)
5. How active were you in providing feedback to researchers about their draft tools or products? Rate from 1 (not active at all) to 5 (very high)
6. Were there enough opportunities to interact with researchers? Tick one box.
   - Too little
   - Just right
   - Too much
7. How would you rate the quality of information you received from researchers? Rate from 1 (poor) to 5 (very high)
8. How would you rate the presentation style of researchers at Climate Champion workshops? Rate from 1 (poor) to 5 (very high)
9. How willing do you think researchers were to listen to your ideas? Rate from 1 (not at all) to 5 (very willing)
10. How responsive do you think researchers were to the questions you asked? Rate from 1 (not at all) to 5 (very responsive)
11. Did you do anything differently because of your interactions with researchers? If so, please describe.
12. Did the researchers do anything differently because of your interactions with them? If so, please describe.
13. What was the best single thing about the Climate Champion Program for you personally?
14. What do you believe was the best single thing about the Climate Champion Program for Australia?
15. Do you have any suggestions for how it could have been improved?

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