The roles of quantitative and qualitative data in evaluation studies

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The situations investigated by educational researchers and evaluators are often very complex. In studies of value and impact, how should researchers best represent these situations in ways that do justice to this complexity yet assist program leaders and funding agencies to make decisions about future directions and funding? What data is most relevant for particular parts of the inquiry and how can it be best used to provide as accurate a picture as possible of a complex situation? The authors will draw upon a recent experience of an evaluation study to examine the relative value of different types of qualitative and quantitative data to serve a range of purposes and audiences. Bruner's distinction between narrative and paradigmatic cognition helps make sense of these distinctions.

Introduction

The primary data used to support the argument presented in this paper comes from an evaluation of the model and outcomes of the Scientists and Mathematicians in Schools (SMiS) program operating across Australia. The program was initiated by the Office of the Chief Scientist and is managed by CSIRO. The authors, together with other colleagues, formed a team that evaluated the model and outcomes of SMiS during 2015.

The Scientists and Mathematicians in Schools program

In this program a volunteer STEM professional is matched to a teacher who has sought such a partnership. In the most common protocol for successful partnerships identified in this study the STEM professional works with the teacher to augment aspects of the school curriculum, often engaging students in working scientifically and mathematically in authentic activity. The SMiS program operates over three areas of the school curriculum: science, mathematics, and information communication and technology (ICT) and is open to teachers operating at all grade levels from all school jurisdictions. The SMiS Program aims are very broad, reflecting the open nature of the model. They are to:

- bring the practice of real world science, mathematics and the ICT profession to students and teachers;
- inspire and motivate teachers and students in the teaching and learning of science, mathematics, and ICT;
- provide teachers with the opportunity to strengthen their knowledge of current scientific practice, mathematical and ICT applications;
- enable scientists, mathematicians, and ICT professionals to act as mentors or role models for students;
- broaden awareness of the types and variety of careers available within the science, mathematics, and ICT fields;
- enable teachers, scientists, mathematicians, and ICT professionals to share ideas and practices with other teachers, scientists, mathematicians, and ICT professionals; and
- increase scientists', mathematicians', and ICT professionals' engagement with the broader community, thus raising public awareness of their work and its social and economic importance.

The program has been operating since 2007. It has grown in size and scope, beginning its operation involving scientists but expanding to include mathematicians and more recently ICT professionals. The total number of partnerships has grown considerably over the years so that the scheme has become a very significant operation, as can be seen from Table 1.

Table 1

*Growth in the numbers and profile of active and assigned partnerships in Science, Mathematics and ICT in schools between 2012 and 2015**

	Partnerships	**Scientist-teacher**	**Mathematician-teacher****	**ICT Specialist – teacher****
30th June 2012	1469	1291	178	
30th June 2013	1539	1348	190	
30th June 2014	1650	1400	250	
30th June 2015	1799	1460	263	76

*Data from the SMiS – Summary 30 June Statistics 2012-2015. ** Note that the MiS program began in 2009 and the ICT in Schools program in 2014

The evaluation

The managers of the program have taken the issue of evaluation very seriously. Significant evaluations of the program have been conducted and published (Howitt & Rennie, 2008; Rennie & Howitt, 2009; Rennie, 2012). The contract for the present evaluation specified a set of questions to guide the evaluation. These related to:

- the outcomes of the SMiS program for both students and teachers;
- the similarities and differences in partnerships in the different discipline areas;
- the strengths of the model compared to the range of initiatives involving STEM professionals working in schools; and
- ways in which the model could be implemented which would enhance its outcomes and impact.

The evaluation contract described the primary audience for the deliverables as members of Parliament and the Federal Departments of Education, Industry, Finance, Treasury, Prime Minister& Cabinet, and CSIRO. However in consultation with the SMiS team, the evaluation team identified a broader range of audiences for whom the report and its findings would be of interest. These expanded audiences thus include:

- Government agencies and parliament as described;
- In CSIRO, in particular the team responsible for the program and the steering committee composed also of DOE representatives;
- Potential funding and participating industry bodies;
- Education professionals;
- The communities of scientific, mathematical, and ICT professionals;
- Educational researchers; and
- The general public.

In the light of these considerations the evaluation team sought to generate data and analyses which could:

- enable interested parties to judge the value of the program;
- assist the SMiS team to improve the efficiency and effectiveness of the operation of the program; and
- provide insight for the educational and scientific communities, in particular, on the challenges and potential of this partnership program model.

The data collection

The three data collection methods followed a pattern developed during previous evaluations. These included a survey, interviews with project officers, and interviews with selected partnerships to develop case-studies. The survey was offered to all relevant teachers and STEM professional who had been matched in partnerships. The survey instruments included items in which respondents were asked to use a Likert scale to record their response to statements and a smaller number of open-ended questions. For a number of the Likert scale items respondents were also offered the opportunity to add explanatory comments.

There were two sets of semi-structured interviews. The first set (seven in total). was with a sample of the CSIRO SMiS Project Officers They were selected by the program manager and included project team members located in state offices

who had responsibility, amongst other duties, for most of the teacher and STEM professional partnering.

A second set of semi-structured interviews was conducted with teachers and STEM professionals in selected partnerships. Selection was undertaken by the evaluation team and was informed by the survey data. The team selected from those participants whose survey response indicated that they volunteered to be interviewed, and included partnership participants who would be likely to provide useful insights into the operations of individual partnerships, and a variety of partnership models. Where possible other relevant people were also interviewed, in some cases this included students.

Reporting the data

The focus of this paper is to consider questions around the reporting of data through an evaluation report when there is a significant quantity of data as was the situation in this evaluation. We will deal with the issues by addressing the questions:

1. What principles underpin the selection of survey data to be included in the evaluation report?
2. What purpose can be served through use of the comments that the survey respondents have made, bearing in mind that the inclusion of comments was an optional extra for respondents?
3. How can the case-studies best be represented?
4. Are particular forms of data better suited to some purposes and audiences than others?

1. What principles underpin the selection of survey data to be presented?

In this evaluation the surveys generated enormous quantities of data and we were faced with the question of how to select data to be included in the report. The quantity of data precluded inclusion of it all. The considerations for data inclusion began by identifying the major themes emerging from the study, bearing in mind the various audiences who would be considering the report. Quantitative data were included if they were seen as significant in establishing the validity of the insights the researchers saw as emerging when all of the data were considered, and omitted if they were judged less relevant to the major themes.

Table 2 contains a sample of the survey data. The question asked revealed the range of benefits the teachers perceived as arising from the partnership. Listing the categories in numerical order allows the reader to judge where the balance of benefits lies, in this case emphasising both attitudinal and knowledge outcomes. The decision to present the percentage of 'very significant' responses was made since this allowed discrimination related to the extent of benefit. Had the percentage figures obtained by combining 'very significant' and 'significant' benefit been presented, all categories would have exceeded 90%, allowing little discrimination.

The presentation of this specific quantitative data showed that, in addition to some anticipated outcomes, about a third of teachers believed that the program had conferred a very significant benefit in improvements in their teaching practice. These data suggest that the program can be viewed from the perspective of teacher professional development as well as for the direct impact on students. The decision to

present the data in this way meant that the outlier data (that of the opposite extreme) were not represented.

Table 2

Teachers' response to: Are any of the following of perceived benefit to you?

Relevant benefit	**Science: % very significant benefit (N=132)**	**Maths: % very significant benefit (N=23)**
Enjoyment in working with the scientist/ mathematician	67	39
Increased engagement of my students with science	64	39
Opportunity to communicate with scientist/ mathematician	59	52
Updating current science/mathematics knowledge	47	35
Updating knowledge of scientific practices/methods	45	30
Increased motivation to teach science/mathematics	40	22
Support for my teaching of the science as a human endeavour strand of the Australian curriculum	36	N/A
Establishes me as a dedicated teacher of science/mathematics	36	22
Improvements in my teaching practice in science/mathematics	34	26
Support for my teaching of the science/mathematics inquiry skills/ mathematics reasoning strand of the Australian Curriculum	29	30

2. What purpose can be served through use of the comments that the survey respondents have made, bearing in mind that the inclusion of comments was an optional extra for respondents?

A second challenge for the evaluators arose from the data generated by the open questions included in the survey. Table 3 sets out some of the responses from teachers to a question about the time commitment of teachers to collaborations around mathematics.

Table 3

Selected responses to the survey question 93 "Please comment on your time commitment dedicated to your involvement in Mathematicians in Schools"

There were 72 responses to this request to teachers. Some examples follow:
• Planning through discussions with scientists using emails, face to face, video conference about 20hours / working with scientists with students for one day / assisting scientists with grant funding application about 5 hours
• I meet up with my partner outside of school hours, either after school, on the weekend or in the school holidays. I've spent several hours planning with my partner, as well as making resources and getting things prepared for activities.
• It is consumed into my regular planning and teaching load.
• 50hours per year.
• I would like to spend more time with Scientists in Schools - limited by my workload.
• 5 hours per year approx.

Although many did not respond to the invitation to comment, amongst those who responded some indicated how much time was involved, others explained how that time was used, and then others (for example, 'It is consumed into my regular planning and teaching load') provided no usable information. These data provide insights into how much time those who added additional comments were committing to the program and how that time was spent. They also provide an *indication* of the range of time spent and the diversity in how that time was used.

This set of data also draws attention to the nature of the model underpinning the program where each partnership is unique, determined by what is negotiated between the teacher and the STEM professional. This issue is further illustrated by the data set out in Table 4.Here again the challenge facing the evaluators is what to take from such data to include in the report.

Rather than focus on the specifics of the individual responses these data, whilst revealing the diversity in what happens in the schools, point to the fact that these partnerships have the potential to provide significant learning for teachers who become involved. For the evaluators the critical tasks are to identify key themes and to select for the report comments from the respondents that illuminate the theme.

Table 4

Survey comments illustrating the outcomes and perceived benefits through interaction with teachers and their STEM professional partners.

Some responses to the survey question, "Please comment on the significant changes that would not have occurred had you not participated in the SMiS Program?"
▪ "Teachers also benefit from observing science being taught effectively, conducting experiments they can then replicate later on for other classes." (Teacher)
▪ "I have increased in confidence and in my understanding of the Science curriculum. It has in turn given me the confidence to run special activities for our students to highlight the fun and learning that Science can provide students. This has had a whole school impact." (Teacher)
▪ "My science teaching involves what I dream about for my students and how others help me achieve my goals through creative problem solving. Our students were exposed by our SIS to hover-board building and slowly we became proficient enough to develop improvements. We have invested significantly in bringing back animals into classrooms. Our Scientist has advised us on materials for innovative stick insect enclosures. We will promote a renaissance in keeping animals in the classroom in 2016 throughout WA once our exquisite animals start breeding. All thanks to the enclosures. Our Scientist has advised me on equipment to revolutionise heat activities with students in primary school. We have built the world's first 3D Printed Harmonograph thanks to inspiration from our Scientist's organisation. Look that one up on Google, the video went viral thanks to 3D Print.com." (Teacher)
Some responses to the survey question, "Were there other perceived benefits for your partner?"
▪ "(The partnership) gave the teacher a chance to see students working on different topics and engaging with creative ideas in approaching mathematical tasks. It also gives the teacher a chance to ask questions of a mathematician, if fellow teachers cannot help". (Mathematician)
▪ "I have found most primary teachers have a limited view of mathematics and perhaps feel a little isolated in dealing with maths. It is good for them to see how students can have fun with maths outside the standard curriculum. One teacher commented to me that she now understood it was more about the thinking process and not the particular numbers." (Mathematician)

3. How can the case-studies best be represented?

As indicated, interviews were conducted with a number of individuals involved in partnerships which had been chosen as case-studies. This method of data gathering proved to be most fruitful as it provided a level of detail about what was happening in partnerships that had not been obtained by the other data gathering methods. The interviews revealed information which supplemented the data gathered through the

survey providing insight into the personal interactions which determined the course of the partnerships.

Consistent with an understanding of the significance of the narrative mode of thought as proposed by Bruner (Bruner, 1991; Bruner, 1996), these case-studies were reported in narrative form. The research team made explicit their intended evaluation foci, and developed narrative parts that communicated the perspectives of the different respondents within each partnership. These narrative parts functioned to structure the narrative as a whole and were expected to help stakeholders make sense of links between these different narrative parts as they interpreted each case. It was expected that stakeholders would be "able to take competing versions of the story with a perspectival grain of salt, much more so than in the case of arguments or proofs" (Bruner, 1991, p. 17).

Seven case-studies were developed from the interview data and it was decided to include them in full in the evaluation report due to the significant insights that they provided into the development and operations of the partnerships. Table 5 sets out an extract from one of the case-studies.

Table 5

Extract from case 4 – a mathematical approach

A mathematical approach
The partner-mathematician, Heather, has visited the school twice since the partnership began less than 12 months ago. She has addressed the year 12 students speaking about, among other things, how mathematics works in her area of employment (astrophysics), and how it is such a big part of getting any job. When Patrick (the teacher) spoke with these students afterwards he noted that this latter point resonated most with them. Patrick hopes that this message might be communicated to all students in the future. Heather has also spent time with the students in year 8 and 9 speaking about how mathematics relates to astrophysics. Patrick was "blown away" by the impact Heather has had on the students so far and has begun planning with Heather to facilitate a project for the year 8 and 9 accelerated students with a focus on the mathematics involved in astrophysics. Some students have also requested that they have one-on-one time with Heather to discuss her area of expertise. Other teachers in the school have been inspired and requested that Patrick "share" Heather with them. He anticipates that this will also happen as the partnership continues.

This case-study narrative provides some significant and varied insights into the involvement of this mathematics professional, the responsiveness of the teacher in enabling her influence to extend further into teaching and learning in mathematics and science in the school, and the awakening of new interests in mathematics for students through extending career aspirations. Such richness would most probably not be detected by a survey where the information gathered relates directly to the questions posed to the individual responding to it and where the people composing the survey have no idea of the nature of individual partnerships.

4. The roles of quantitative and qualitative data for this study

Attention was drawn earlier in the paper to the range of people who are likely to take an interest in the evaluation report. The focus of this paper is whether some forms of data, and hence data collection methods, have greater relevance for some purposes and for some readers of the report than others. Consideration of these purposes and audiences is important in thinking about the value of the various forms of data and their presentation in the report.

Ultimately all parties are interested in the question of whether the aims of the program are being met. However, this question cannot be answered simply for programs such as SMiS where the objectives are very broad and diverse. More accessible are the questions:

What actually happened in the partnerships? and

What processes influenced the nature of activities and outcomes?

To illustrate the role of the various forms of data we shall explore their contribution to answering these questions.

The survey provided numerous sets of data that relate to these questions. For example, it included, but was not limited to, quantitative data on issues such as what proportions of the scientists contributed in the broad discipline areas, physics, biology etc., the extent to which the partnerships impacted beyond the individual teacher and their students, as was shown to be a relatively common occurrence in primary schools, on the motivation which prompted the partners to become involved in the program, on perceptions of the participants on the support materials and activities provided by the SMiS team, on the activities engaged in and time spent, and on perceptions of the outcomes for students and teachers.

In addition the opportunity for participants to report, in their own words, on various issues provided the evaluators with additional information on which to draw in order to obtain a more complete picture of the program in operation. Much of these data, as was illustrated in Tables 3 and 4, revealed the diversity of practices and opinions across the range of partnerships allowed using the SMiS model.

The data obtained from the interviews with the SMiS team raised some interesting questions for the evaluators to pursue and hence were important in generating data of concern to many audiences. For example, these interviews drew attention to the importance of effective communication between newly established partners in establishing the scope and focus of the partnership. “I also think another aspect of a successful partnership is just building an appreciation of the requirements that each other has in their careers” (SMiS Team Member PO230).

The importance of early and open communication between partners to the success of the venture was illustrated much more clearly when the data from the case-studies were analysed. Extracts from case-studies demonstrate the point:

> George notes the need for the partners (teacher and scientist) to be sensitive to each other’s skills, have sensitive communication skills, and the need for flexibility. Each school manages their partnerships with him in a different way; he acknowledges that an awareness of this is helpful for a successful partnership. (Case 6)

> This active partnership began in term 1 2014. The scientist, called Kelly, works part time and was flexible with timing. She was willing to volunteer for 2 hours per week. Initially, Kelly and Alice met every fortnight, for quite a few weeks to discuss how Kelly could be best utilised in the school. These conversations were important in establishing the scientist's interest and skills, orientating the scientist into the school and gaining an understanding of each partner's objectives. (Case 2)

The narratives which were generated by the case-studies were vital to the evaluators gaining insight into the specifics of what was happening in the schools when the partnerships were operating, and provided rich opportunities for different stakeholders to interpret them in terms of their own focus of interest. As identified by Bruner (1991) in examining narratives, they told a story that went beyond the survey data or even the shorter commentaries in the survey, that themselves added insights into what the quantitative data categories were revealing. Thus, to make sense of what is going on in this complex and sometimes contradictory environment, the three types of data analysis undertaken contributed to:

a) constructing an overview of the balance of participants' experience,

b) gaining insight into what the different survey categories mean, and

c) gaining some insight into how these multiple perspectives and experiences play out in the lived experience of STEM professionals and teachers on the ground.

Returning to the central question for this paper, the relevance of the various data forms to the disparate purposes and audiences to be served by the report, we would argue that it is inappropriate to suggest that any particular form of data is exclusively relevant to a particular audience. Rather our thesis is that the data together are necessary to build a more complete picture which will provide the understandings of this complex operation that are necessary for the multiple purposes of the report, and the multiple audiences. Policy makers need not only an account of the 'on balance' outcomes for students and teachers, but also some insight into what could be done to enhance the impact of STEM education in schools. Similarly, the SMiS team needs to be assured of the overall balance of outputs and outcomes and nature of operation of the partnerships, but also needs detailed insights from stories of participants' experience and perspective to gain a sense of how to respond to the various partners' needs. Finally, prospective SMiS participants may be swayed by stories of the nature and outcomes of partnerships and also profit from assurance of the overall balance of activities and outcomes that can be expected.

Reflections on the methodology employed

The theoretical perspective developed by Bruner and others (Bruner, 1995; Bruner and Polkinghorne, 1996) provides a set of related concepts around scholarly inquiry which can usefully be applied to the framing of this study. Bruner designates two types of cognition: paradigmatic, which operates by recognising elements as members of a category; and narrative, which operates by combining elements into an emplotted story. Paradigmatic inquiry uses paradigmatic analytic procedures to produce taxonomies and categories out of the common elements across the database. Narrative

inquiry gathers events and happenings as its data and uses narrative analytic procedures to produce explanatory stories. Clearly both of these have been employed during this study. We have drawn findings from quantitative data gathered by the survey and we have constructed narratives from the qualitative case-study interviews. These twin concepts highlight the problem faced by evaluators of a program such as SMiS in that, while each partnership is unique, the evaluators are challenged to seek common patterns, which can guide those responsible for the program to strengthen its operation.

Bruner highlights this challenge when he proposes that the purpose of narrative cognition is to create meaning rather than truth. In this study we have created narratives to give readers some insight into what is happening on the ground when the SMiS model is applied. We cannot claim to have revealed the truth about the program.

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