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Motivational features of science shows

A thesis submitted for the degree of

Doctor of Philosophy

of

The Australian National University

by

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Canberra

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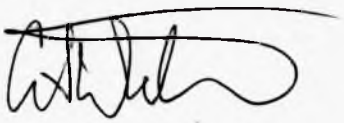
Declaration

This thesis is my original work. None of the material has been submitted previously to any university or other educational institution as part of a degree, diploma or other qualification. To the best of my knowledge, this thesis contains no material previously published elsewhere, except where reference is made.

Where investigations were conducted with the assistance of others, I was entirely responsible for all high-level research-related aspects of the project. During the HIV AIDS study only, others assisted me with occasional low-level tasks such as completing a minority of the data entry and other administrative tasks (e.g. photocopying and distributing surveys). Regarding the paper I cite where I was the lead author, I was responsible for all writing and research activities; co-authors (supervisors) assisted with editing only. Content from this paper has been incorporated into this thesis.



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Abstract

This thesis investigates how science shows affect audience motivation. Science shows – sometimes termed science theatre or lecture-demonstrations – are a form of informal science learning, often performed in science centres, museums and schools. Despite their wide use, little research has been conducted on science shows, and less still on their use as motivational tools. This lack of knowledge hinders development of motivational science shows and hence restricts impacts they have on audiences – especially in addressing societal problems where motivating people is part of the solution, such as with health and environmental issues.

This research identified potential motivational features, and then tested whether they were associated with short-term motivation from a science show. Quantitative data were collected from eight different shows which had varying motivational aims: broadly improving attitudes to science, inspiring future study and careers, and influencing behaviours related to climate change and HIV AIDS. The motivational features investigated were mainly associated with situational interest and intrinsic motivation theories, including value/relevance, curiosity, immediacy (enthusiasm, humour and interaction), and the emotions of interest, enjoyment and surprise. Prior experience and prior knowledge, and cognitive learning were of secondary importance. Scales were developed to measure these motivational features. Regression analyses identified relationships between the motivational features and motivation, and between the motivational features themselves.

Results demonstrate that science shows are effective motivational tools for a range of outcomes. Hence, informal science learning providers should consider their wider use, especially in addressing important societal issues. The key feature of a motivational

science show is value, i.e. linking content to real-world contexts that are personally meaningful to audiences. Other audience characteristics also affected motivation: participants with lower prior motivation and/or younger ages reported greater motivation. The motivational impacts of other features depended on show content, desired outcomes, age and other factors. Immediacy and interest-enjoyment were particularly associated with motivation in youth, whereas curiosity was a more effective motivator in older age groups. The research highlights how curiosity and interest differ, the associated role of surprise, and proposes models of how such constructs and discrepant events operate. Recommendations for science show practice are given.

Table of contents

Chapter 1. Introduction 1

1.1. Background 1

1.2. What exactly is a science show? 3

1.3. The research problem 5

1.4. Research questions and purpose 7

1.5. Overview of the methods 8

1.6. Why this research matters 9

1.7. Scope and limitations 10

1.8. Thesis synopsis 12

Chapter 2. Literature review 1: Motivational models, value and emotion 13

2.1. Introduction and overview of structure 13

2.2. Motivational models, variables and science shows 18

2.3. Value as a motivational variable 25

2.4. Emotion as a motivational variable 38

2.5. Interest, enjoyment and surprise 53

2.6. Summary: motivational models, value and emotion 64

Chapter 3. Literature review 2: Curiosity, immediacy and science show motivation 66

3.1. Curiosity as a motivational variable 66

3.2. Enthusiasm and immediacy: a motivational feature for science shows? 82

3.3. Motivational outcomes from ISL and science shows 94

3.4. Findings of the literature review 98

Chapter 4. Methods 102

4.1. Overview and introduction 102

4.2. Research methodology 102

4.3. Shows investigated 107

4.4. Samples 116

4.5. Survey design 117

4.6. Data collection 127

4.7. Data processing and statistical analysis 128

4.8. Limitations of the method 136

4.9. Summary 141

Chapter 5. Results 143

5.1. Overview 143

5.2. Shows with subtle motivational outcomes 146

5.3. Same show; subtle and overt outcomes 157

5.4. Shows with overt motivational outcomes 171

5.5. Summary: What features of a science show are motivational? 188

5.6. Sub-questions 197

Chapter 6. Discussion: What features of a science show motivate people? 217

6.1. Overview 217

6.2. Context: show settings and sample characteristics 218

6.3. Do science shows motivate people? Motivational outcomes and change 221

6.4. Relationships of motivational outcomes with motivational features, age and gender 228

6.5. Which motivational features identified were associated with motivation? 233

6.6. Key findings regarding the role of motivational features, age and gender 254

6.7. Sub-questions emerging from the literature review 256

Chapter 7. Conclusions and implications 271

7.1. Answers to the research questions 271

7.2. The motivational features investigated 272

7.3. Tailoring motivational features to audiences 299

7.4. What about other motivational features? 304

7.5. Limitations 308

7.6. Précis of recommendations 312

7.7. Overall implications of this research 315

References 318

Appendix A: scale items 335

Appendix B: survey instruments 351

Appendix C: ethical approval and information sheets 371

List of figures

Figure 1. Overlap of motivational theories including situational interest (SI), intrinsic motivation and expectancy value. 21
Figure 2. Relationships of the motivational features indicating models and sub-questions. 99
Figure 3. Overview of statistical analysis and links to the research questions. 130
Figure 4. Overview of the Chapter, including studies presented and the type of motivational outcomes investigated 144
Figure 5. *Booming*: age (note the 17-20 category which was empty is not shown).... 147
Figure 6. *Ballistics*: age 155
Figure 7. *Burning Public*: age 160
Figure 8. Beta values for predictors of motivation in different groups. Unshaded bars represent non-significant predictors. 165
Figure 9. *Sustainability 2010*: age 180
Figure 10. *Sustainability 2011*: age 184
Figure 11. All studies: beta values for predictors of motivational outcomes or change. Note: non-significant predictors are unshaded. 192
Figure 12. All studies: age and gender standardised beta values when predicting motivational outcomes or change. Non-significant predictors are unshaded. ... 196
Figure 13. Overview of chapter structure. 218
Figure 14. Proposed surprise to curiosity process for youth and adults. 243
Figure 15. *Burning Public*: motivational feature relationships (all ages) and predictors of motivation in youth, adults and all ages. 268
Figure 16. The three levels of value showing value becoming more specific to the individual. 279

List of tables

Table 1: 6-item value scale used in *Burning Issues* public shows....123
Table 2: 3-item surprise scale used in *Burning Issues* public shows. 125
Table 3. *Booming*: gender by age....146
Table 4. *Booming*: scale scores and reliabilities....148
Table 5. *Booming*: regression onto motivational outcomes....149
Table 6. *QVC*: gender by age....150
Table 7. *QVC*: scale and item scores and reliabilities....151
Table 8. *QVC*: regression onto motivational outcomes....153
Table 9. *Ballistics*: gender by age....155
Table 10. *Ballistics*: scale scores and reliabilities....156
Table 11. *Ballistics*: regression onto motivational outcomes....157
Table 12. *Burning Public*: gender by age....159
Table 13. *Burning Public*: scale scores and reliabilities....161
Table 14. *Burning Public*, all ages: regression onto motivational outcomes....162
Table 15. *Burning Public*, adults: regression onto motivational outcomes....163
Table 16. *Burning Public*, youth: regression onto motivational outcomes....164
Table 17. *Burning Schools*: gender by age....165
Table 18. *Burning Schools*: scale and items scores and reliabilities....166
Table 19. *Burning Schools*, all ages: regression onto motivational change....168
Table 20. *Burning Schools*: pre, post and change in motivation for each item (for full wording see Appendix A). Grey indicates non-significant changes....171
Table 21. *HIV*: demographics, gender by background and age....172
Table 22. *HIV*: scale and items scores and reliabilities....174
Table 23. *HIV*: regression onto motivational change....175
Table 24. *HIV*: motivation change across individual items. Non-significant changes are in grey....178
Table 25. *Sustainability 2010*: gender by age....179
Table 26. *Sustainability 2010*: scale scores and reliabilities....180
Table 27. *Sustainability 2010*: regression onto log motivational outcomes....182
Table 28. *Sustainability 2011*: gender by age....183
Table 29. *Sustainability 2011*: scale scores and reliabilities....184

Table 30. *Sustainability 2011*: regression onto motivation change 186
Table 31. *Sustainability 2011*: motivation change. Non-significant changes are in grey. 188
Table 32. *Sustainability 2011*: knowledge change. Non-significant changes are in grey. 188
Table 33. Adjusted R Square values for regression onto motivational outcomes or change, all studies 189
Table 34. All studies: standardised beta values for predictors of motivational outcomes or change 191
Table 35. All studies: age and gender standardised beta values when predicting motivational outcomes or change 195
Table 36. *Burning Public* all ages: correlations between emotions, motivational variables and age. 198
Table 37. *Burning Public* all ages: correlations between interest-enjoyment and immediacy items, and between immediacy items. 199
Table 38. *Burning Public*: factor analysis of all items 201
Table 39. *Burning Public*: factor analysis of motivational features only 203
Table 40. *Burning Public*: factor analysis of surprise, curiosity and interest-enjoyment items. 204
Table 41. *Burning Public*: factor analysis of surprise, curiosity and PEPK items. 205
Table 42. *Burning Public*: regression onto curiosity 206
Table 43. *Burning Public*: regression onto surprise 207
Table 44. *Burning Public*: regression onto interest-enjoyment 208
Table 45. *Burning Public*: regression onto immediacy 209
Table 46. *Burning Public*: regression onto value 210
Table 47. *Burning Public*: regression onto PEPK 211
Table 48. *Burning Public*: standardised beta values for predictors of motivational features. 213

Chapter 1. Introduction

> It is surprising how often people in all walks of life own that their interest in science was first aroused by attending one of these courses when they were young, and in recalling their impressions they almost invariably say not 'we were told' but 'we were shown' this or that.
>
> Sir Lawrence Bragg (Faraday & Bragg, 1974, Illustrations and experiments section, para. 5)

1.1. Background

People with a passion for science often have cause to reflect on the moment that their interest in science was first realised – when motivation to explore science took hold. For me it was hands-on play and experiment with my father, for others a chance encounter at a zoo, for you something else again. The 'courses' Bragg was referring to above, to add to the list, were the historical forerunners of modern demonstration-based science shows – the subject of this research. Science shows, often termed science theatre or lecture-demonstrations, are a widely employed, yet little researched, form of informal science learning (ISL). They involve a presenter(s) using dramatic techniques and demonstrations to communicate science to audiences in an engaging way.

As Bragg alludes to in the quote above, most ISL settings such as science centres and shows aim for affective outcomes (Beetlestone, Johnson, Quin, & White, 1998), such as sparking interest and building enthusiasm for science – science 'learning' in the

broadest sense. Traditional cognitive learning outcomes, as prized by the formal learning sector, are still an aim, but ultimately ISL is more about sending people away with a feeling than with a fact – one would hope both.

ISL takes on many forms. ISL happens as part of everyday life experiences (National Research Council, 2009) such as playing in a rock pool, however many organisations and settings also provide structured ISL experiences. Rennie (2007) divides these into three categories: (1) museums, science centres, zoos and similar public institutions; (2) community organisations, who often champion causes such as health or the environment, and (3) the media, including print, broadcast and web-based forms. Science shows generally sit as a subset of category one; they are part of in-venue and outreach programs provided by institutions such as science centres and museums. A show experience is distinct from interacting with an exhibit, so they fill an important niche in the offerings of science centres and similar institutions, as noted by Ucko (1991, p. 5):

> Theater provides an educational tool that complements those traditionally used at science centers. Plays are "live" in every sense, and compensate for the more impersonal nature of most exhibits. They are excellent vehicles for creating emotional involvement in a subject, stimulating interest, or raising issues such as social impact.

These comments hint at an overlap between Rennie's (2007) categories: occasionally science centres and shows will deal with social issues, or community groups and individuals who are passionate about certain causes will use science shows. Consistent with Rennie's analysis, principal amongst these issues are health and the environment. For example, science centres and museums have been used to try and reduce illicit

drug use (Cartmill & Day, 1997) and to communicate climate change (Association Of Science-Technology Centres, 2011). These ISL activities build on the affective outcomes mentioned earlier, honing a general interest in science into feelings and attitudes that may motivate people to take action on social issues related to science. In this way, science centres and their science show programs become agents of change, aiming to extend their positive influence from the individual to the whole of society and its problems. For science centres and shows this aim is not the norm. Yet some theorists argue their ultimate value is fundamentally based on such aims, such as in Weil's (2002) book *Making Museums Matter*, as noted by Koster and Falk (2007, p. 1):

> Museums [or science centres] should exist not just for the scholar or elite, but for the greater good. The premise that museums should matter in this way is an intensely responsible proposition. To pose the opposite question – why would a museum wish not to benefit society and/or the environment in the greatest possible way? – is to emphasize the choice now being presented to the museum field. Surely, today, the most compelling rationale is that, locally and globally, the myriad of opportunities and challenges faced by society and the environment would greatly benefit from the kind of informed perspective museums could provide.

The aims described above are, however, not the typical domain of a science show. Perhaps this is because we know little of how to use them as motivational tools, or even if they motivate people in the first place.

1.2. What exactly is a science show?

For the purposes of this thesis, a science show is defined as a live performance on the subject of science that must include demonstrations as a major component, given by

one or more presenters to an audience which is able to interact. This definition is deliberately broad, however the key inclusion of demonstrations rules out closely related genres such as museum theatre, which usually differs from science shows by greater use of characters, narrative and focus on dramatic techniques as opposed to use of demonstrations (Bridal, 2004). The boundaries between science shows and museum theatre are blurry and many presentations fuse elements from both.

The use of demonstrations to communicate science, however, is typically the key difference and highlights the origins of science shows as 'lecture-demonstrations' – a term still used to describe shows in academic circles. Taylor (1988) gives a wide yet sound definition of a demonstration as:

> Generally speaking a demonstration means the illustration of a point in a lecture [show] or lesson by means of something other than conventional visual-aid apparatus. I like to divide demonstrations into three categories: (1) visual-aids using non-conventional apparatus; (2) analogue demonstrations... [using] a phenomenon sufficiently similar to that being discussed to make it valuable as an instructional aid... ; [and] (3) real experiments. (p. 59-60, 63)

The definition of science shows proposed here also excludes some formats that are beyond the scope of this research. Some exclusions are worth noting, such as pre-recorded science shows which are not live or interactive (i.e. a DVD), live broadcasts of science shows where direct presenter-audience interaction is not possible (e.g. live TV broadcasts), or pre-recorded science demonstrations (e.g. science TV programs, YouTube, etc.). Note the definition does include video conference formats where two-way communication and interactions between presenter and audience are possible.

1.3. The research problem

Annually, 310 million people in 90 countries participate in science centre programs (6th Science Centre World Congress, 2011) and although statistics on the proportion exposed to science shows are not available, even a fraction of this constitutes a lot of people. Compared to their reach, the impacts of this worldwide effort of 2500 science centres (ibid.) are under researched, evidenced by recent reports trying to quantify the value of science centres. Frontier Economics (2009) summarised the problem in the United Kingdom thus:

> We have not been able to assess whether science centres are good value for money relative to other comparator programmes. Overall, there is a disappointingly low amount of evaluative evidence for both science centres and comparator programmes.

Despite these issues, there is evidence that science centres make a difference to their audiences, such as research by Falk and Needham (2011) on the Los Angeles Science Centre:

> Results suggest that the Science Center is having an important impact on the science literacy of greater L.A. More than half of residents have visited the Science Center since it opened in 1998 and self-report data indicate that those who have visited believe that the Science Center strongly influenced their science and technology understanding, attitudes, and behaviors.

It is reassuring that the efforts of science centres are making a difference to their visitors, however whether science shows contribute to that difference is poorly understood. As a show performer for the past 12 years, it is something I have often

wondered myself. Do my shows actually make a difference? This was where this PhD project began. As will be discussed in Chapters 2 and 3, there is a paucity of research to answer the fundamental question of what impact – motivational or otherwise – a science show has. Hence, extension questions such as how science shows can make a greater impact, and what kind of impacts are possible, also remain largely answered. This lack of knowledge holds science shows back in many ways: presenters lack evidenced-based ways to design and improve shows; organisations may be unaware of what kind of issues may be tackled via shows; funders may question the value of shows (as they do science centres); and, ultimately, the positive impacts on audiences are reduced. In sum, despite knowing that science centres can strongly influence visitor's attitudes and behaviour (ibid.), the role science shows can play in this is unclear.

As noted in the previous section, some theorists believe that a fundamental activity of museums and science centres is to tackle society's challenges for the 'greater good'. Put another way, these institutions should influence the way people feel, think and behave – motivate them – to improve their lives and the wider community. Can science shows help in this aim to motivate people? There is evidence that ISL can motivate people, but we are yet to discover in any detail if this extends to science shows.

One outcome of this is that science shows are rarely framed as motivational tools, despite being used to encourage positive attitudes to science, inspire further study and promote science careers. Rarer still, however, is the application of shows to deal with specific challenges where people need to be motivated to take action, such as climate

change. That science shows are not more widely applied to such problems is a problem in itself, probably fuelled by the lack of research on their efficacy.

1.4. Research questions and purpose

This research, first and foremost, is about understanding motivation from a science show. It addresses the fundamental question of whether science shows can be effective motivational tools. This extends from more common uses of shows to motivate further thought, activity and positive attitudes to science, through to innovative applications of science shows to motivate action on societal issues. This latter aspect is an important aim as science shows are rarely employed to tackle community problems. This research aims to test if shows related to issues like health and the environment can be motivational for audiences. The purpose of all this is to learn how to motivate audiences with science shows and encourage their broader and more effective use.

To assist in this latter aspect, a second objective is to determine which aspects of a science show appear to be responsible for motivation. A deeper understanding of this will provide targeted ways for show presenters to create motivational shows. Indeed, a key purpose of this research is to apply existing theory, conduct empirical research and develop models that yield practical approaches for show presenters to foster motivation.

Collectively, these purposes will be achieved through answering a central research question: What features of a science show motivate people? Throughout this research this question is asked in two parts, reflecting the aspects discussed in the two paragraphs above:

1. Do science shows motivate people?

2. If so, what are the motivational features of a science show?

These questions provide a starting point for the research and will be refined over the following chapters.

1.5. Overview of the methods

To provide a framework to answer the research questions, the first step was to locate the questions within existing theory, in this case psychological research on motivation. The motivational literature was contrasted with that of formal and informal learning – including the small literature on science shows – to establish which features of a science show appear likely to be involved in motivation. Methods to measure these potential motivational features and motivation were then developed.

Data were collected at performances of eight shows that spanned different topics, styles, performers, audiences and settings. Pre-existing shows were used to collect data on motivation from typical science shows, however two novel shows were developed to investigate motivation with regards to societal issues – climate change and HIV AIDS (which was researched in South Africa where it is an acute problem). Data were either collected immediately following the show (post-only design, with items worded to capture motivation change) or before and after the show (pre-post design, generating a score for motivation change).

Statistical analyses were employed to determine if motivation was significantly changed. Linear regression models were used to establish the association of the different motivational features (independent variables) with motivation (dependent variable), and the effect of basic demographic factors such as age and gender. Finally,

these findings were reintegrated with existing theory to develop models that suggest structured ways to use the motivational features.

1.6. Why this research matters

Globally, hundreds of thousands of people see science show performances annually at science centres, science festivals, schools and many other locations. There is, however, little published knowledge or research on these shows. Much 'research' is in the form of institution-driven evaluation, often clouded by institutional agendas, lacking depth and rarely disseminated. So although science shows are a broadly used ISL format, there is scarce empirical knowledge about how or if they are effective and whether they influence audiences. My research addresses this gap. This is an original contribution useful to the research community, science show presenters, and providing institutions.

Specifically, the most significant aspect within this research is the exploration of using science shows to influence motivation. This contribution is twofold. First, traditional shows often aim for broad motivational/attitudinal outcomes such as fostering positive views of science. Despite this being a common aim for many shows, knowledge about what leads to these outcomes is rare and of limited depth. My research addresses this. The findings here are relevant to the many groups using science shows to influence broad motivational/attitudinal outcomes – i.e. to 'make science fun' – such as science centres, science festivals and providers of school-based programs.

Second, there is an opportunity for science shows to be used more directly to influence specific motivation and behaviour and in turn address issues of concern to

the community. This approach is rarely used in science shows, however may be able to help address serious issues like climate change and HIV AIDS. My research makes a valuable contribution by pioneering such shows and then researching what makes them effective. Applying science shows to tackle societal problems is underutilised and poorly understood by show presenters and providing organisations, however it is potentially life changing for audiences.

A final point of significance is the application of psychological models to understanding ISL and science shows, which has implications from both perspectives. From the science show perspective, this is relevant as the lack of academic research in the area means there are few frameworks to structure understanding and underpin practice. Psychology has made great advances in understanding affect, motivation and learning and, while researchers have begun applying psychological models to ISL (e.g. Dohn, 2011), they are still underutilised – particularly with science shows. From the psychology perspective, testing models in authentic settings like a science show increases the ecological validly of models and expands generalisability. Science shows and ISL, in particular, offer a distinct environment to where many psychological models are developed (i.e. in 'lab' settings or formal learning). Given the free-choice nature of most science shows where people attend mainly for intrinsic reasons, they represent a rich environment to investigate motivation; similar observations have been made on studying relationships between affect and cognition in ISL settings (Dierking, 2005).

1.7. Scope and limitations

Some general limitations of this research should be kept in mind during interpretation, primarily implications of the method and generalisabiltiy. These issues are discussed in

detail in later chapters but are mentioned in brief from the outset to put this research in perspective.

The methods employed here provide a short-term snapshot of motivation from a science show. They are indicative of motivation immediately after the show and hence provide limited insight into whether that motivation is sustained or if it influences behaviour change. Initially a longitudinal study was planned, however the scarcity of research on science show motivation meant that prior evidence of which variables were important was primarily anecdotal. Moreover, there were no reliable measures for science show motivation and influencing variables. Put simply, the lack of research on science shows in general means there is no foundation on which to base longitudinal studies. Hence, it was decided to conduct short-term studies to address the problems noted above, which then lay the empirical foundations for future work.

This thesis draws on a wide range of science shows, which involved different presenters, audiences, topics, motivational aims and settings. These efforts improve generalisability, however the shows selected are only partially representative of the vast diversity of science shows in existence. They also feature demonstrations as a critical element, hence are less generalisable to formats which do not. More broadly, while science shows share many of the fundamental qualities of other ISL settings – such as being free-choice activities (excluding shows for school students) and communicating science through physical examples – they are not representative of all ISL environments. This is principally due to the show format, which is presenter-led and despite being interactive the audience are mainly observers. This experience differs from the highly hands-on experience of a science workshop or science centre

exhibit, although shares similarities to a guided nature walk or a science TV program. Hence, the findings generalise better to some ISL environments than others.

1.8. Thesis synopsis

This thesis is arranged as follows. Following this introduction, Chapters 2 and 3 review literature relevant to the research questions with the primary aim of uncovering possible sources of motivation during a science show, termed *motivational features*. Formal and informal learning literature, combined with emotion and motivation psychology points to a number of variables that appear likely suspects as motivational features, and raises several research sub-questions about how these features are related. Chapter 4 then outlines the quantitative methods used to answer the research questions, including the development of instruments and statistical analysis. It also describes the eight shows studied and outlines the 10 data sets analysed from them, each referred to as a *study* or collectively as *studies*.

Chapter 5 presents results relevant to whether science shows are motivational and if so what role, if any, the motivational features identified from the literature play. It also presents data on relationships between the motivational features, which is important for a complete picture of science show motivation. Chapter 6 discusses these results, answers the research questions and sub questions, and proposes models to explain how the motivational features operate. Finally, chapter 7 outlines the conclusions of this research with regards to the research questions and implications for theory and practice.

I begin by identifying potential motivational features to be investigated over the following two chapters.

Chapter 2. Literature review 1: Motivational models, value and emotion

2.1. Introduction and overview of structure

2.1.1. Review rationale and relation to the research question

The question driving this research is: What features of a science show motivate people? This question can be asked in two parts, (1) do shows motivate people, and if so, (2) what are the motivational features of a science show? The scarcity of research on science shows means there is little literature to thoroughly answer either of these questions, hence this research being conducted.

Science shows do, however, share things in common with other learning environments. Most closely associated are other informal learning environments, such as science centres and museums, especially those in the domain on science. This review will utilise literature in these areas to shed light on science shows. Formal learning environments, on which there is a rich literature, also have relevance when trying to understand science shows. There are many parallels between teacher and show presenter, such as their need to connect with their students or audience, their use of demonstrations, and importantly for this research: their desire to motivate.

The crux of this research is understanding motivation in a science show context. People have been thinking about what motivates themselves and others for a very long time, probably from the dawn of human civilisation (Deckers, 2010). Psychology's ideas about motivation have largely not been applied in understanding science shows, though have been somewhat applied in informal learning and widely applied in formal

learning and everyday life. One of the primary aims of this review is to identify variables that motivate in other settings, so that they can then be tested in a science show context. Literature focused on what motivates people in general and in formal and informal learning will give the best indication of which motivational features may operate in a science show (part two of the research question). Although the literature will also give some indication of whether science shows motivate people (part one of the research question), very little research has addressed this question.

2.1.2. Argument overview and structure

This review is structured in line with the rationale presented above. Using the various literatures noted, I will identify features that are likely to be motivational during a science show. I will also review evidence of motivation resulting from learning settings (and science shows, although this is scarce). This review is structured as below over the next two chapters.

This chapter begins by putting science shows in context, looking at historical and contemporary science shows. I then move to the main thrust of the review, investigating models of motivation and motivational variables applied in learning settings, and of these, which are relevant to the less achievement-oriented context of a science show. This review identifies three models of potential importance, however those including value and emotion appear most apt for science shows. Unpacking these models identifies a number of variables that appear likely candidates for science show motivation. Chapter 3 turns to two other motivational features that may be particularly important during science show – curiosity and immediacy. I then review literature on motivation from science shows and other ISL settings. Chapter 3

concludes with a summary of this review, assessment of gaps in the literature and a refinement of the research questions.

2.1.3. Origins of science shows

The origin of contemporary science shows traces back to The Royal Society in London in the late 17th century where John Keill gave public lectures on Newtonian mechanics (Taylor, 1988) – a subject still popular in shows today (including those in this research). It was, however, the efforts during the 19th century of Sir Humphry Davy and his successor at the Royal Institution, Michael Faraday, which are usually credited with planting the seeds of modern lecture-demonstrations and science shows (e.g. ibid., Sadler, 2004). Davy's 'shows' became popular with the public, including high society and royalty (James, 2002), and embodied elements described in the contemporary definition of shows given above, including interaction with the audience. Selecting a volunteer to inhale nitrous oxide – 'There was Respiration, Nitrous Oxide, and unbounded Applause. Amen!' wrote Davy on his early lectures (quoted in Holmes, 2008, p. 287) – is not likely to feature in today's shows, though may get a laugh if it were. Davy had a major impact on science, discovering many new elements and inventing devices like the miner's headlamp, but he also shared that science with the public and other scientific disciplines and, with mixed results, motivated them to embrace it:

> His recommendation that nitrous oxide (laughing gas) be employed as an anaesthetic in minor surgical operations was ignored, but breathing it became the highlight of contemporary social gatherings. (Chemical Heritage Foundation, 2010)

Before retiring, Davy appointed Michael Faraday to the Royal Institution. He was the next major pioneer of the science show and probably the most instrumental figure in the early development of the genre – including reflecting upon the nature of demonstration-lectures themselves. Faraday, whose scientific legacy is immense and included discoveries such as magnetic fields and electrolysis, is a fine example of someone whose interest in science was sparked by (in today's terms) science shows. Faraday is evidence that these short encounters can spark interest and motivate future careers, as noted by Bragg in the quote at the start of this chapter. Faraday's beginnings are described by James (2002) in a historical account of the Royal Institution's lectures:

> Towards the end of his apprenticeship a customer at the bookshop saw Faraday's lecture notes and gave him tickets to attend the last four lectures to be delivered by Davy in the Royal Institution's theatre. Faraday took detailed notes of the lectures and sent them to Davy asking for a job in science. After a complex set of events Faraday was appointed to the Royal Institution in March 1813. Thus Faraday owed the beginning of his career in science to the lecture theatre, and it seems unlikely that he forgot this debt. (p. 226)

Perhaps this debt is why Faraday was such an exemplary performer and invested himself greatly in creating better lecture-demonstrations. Faraday was probably the earliest science show theorist and spent time analysing what made a good lecture, including setting, audience, delivery, the presenter, lecture content, and the importance of demonstrations (ibid.). He is even cited as resolving to never again present a lecture sans demonstrations after delivering a standard lecture in 1854; indeed, it was an area he felt strongly about:

> He never merely *told* his hearers about an experiment, but *showed* it to them, however simple and well known it might be. To a young lecturer he once remarked: 'If I said to my audience, "This stone will fall to the ground if I open my hand," I should open my hand and let it fall. Take nothing for granted as known; inform the eye at the same time as you address the ear. (Thompson, 2005, p. 232, original italics)

Contemporary science shows owe much to Faraday and could still learn a great deal from him, a very small portion of which is contained in this dissertation. In a way, Faraday's shows live on through his establishment of the Royal Institution's Friday Evening Discourses and Christmas Lectures for children and families, which continue to this day. Modern show performers share Faraday's goal 'to make science a polite entertainment requiring the sort of suspension of disbelief that is associated with the theatre' (James, 2002, p. 227). Moreover, for the most part, they share the goal of the Royal Institution which 'has been and remains to inspire audiences, not necessarily to educate them' (ibid., p. 227).

2.1.4. Contemporary science shows

The average 21st century science show is not so different from those presented by Faraday; it is interactive, demonstration-based, favours inspiring and motivating over educating, requires consideration of the audience, thrives with deft presentation, and typically deals with physics and chemistry (though most disciplines are embraced). Audiences are primarily family groups in public settings or school students in organised incursions/excursions. Presenters may be scientists or actors, but all use dramatic tools and public speaking techniques to communicate science. Shows are provided by a range of organisations, from science centres and universities to Government backed programs and freelance operators. Beyond simply communicating science, the aim of

most science shows is to foster positive attitudes about science, spark interest and inspire curiosity and further thought. Hence, most science shows performed today are about broad subtle examples of motivation.

A rarer form of science show aims to motivate specific behaviour, often relating to a societal issue. It employs all the tools noted above to deliver a focused science-based message that aims to influence the audience's attitudes, motivation and behaviour in targeted ways. Although examples are scarce, these shows usually focus on motivating action relating to the environment, such as recycling (Our Planet Enterprises, 2008), or on health, such as reducing smoking (Koster & Baumann, 2005) or tackling HIV AIDS (Walker, Stocklmayer, & Grant, 2011). From instances found during this research, most shows in this area tend to use more theatrical devices like characters, costumes and special effects and far fewer demonstrations. The success of shows such as these ultimately hinges on knowing how to motivate the audience.

2.2. Motivational models, variables and science shows

2.2.1. On which models should this research focus?

Discovering what drives people is a central concern of psychology, so motivational models are plentiful. Many major theories exist, which have been subdivided, combined and adapted into a seemingly limitless number as they are applied to areas like education, career choice, or health. So which are most relevant when investigating motivation from a science show? A science show or other ISL experience – unlike learning in a science classroom, a student studying for a test, or an adult learning to aid career development – is not typically goal directed. People attend shows for a variety of reasons, but rarely with specific achievement goals in mind. While people may come to shows to learn and appreciate the educational experience, they are also

not primarily driven to master the scientific content. Hence, science shows and ISL settings, in part driven by the fact that they are 'leisure' activities, are situations where goal and mastery orientations to motivation are less important. People are instead intrinsically motivated. Given their free-choice nature, shows can be described as intrinsically motived learning, as defined by Malone and Lepper (1987):

> We define intrinsically motivated learning as learning that occurs in a situation in which the most narrowly defined activity from which the learning occurs would be done without external rewards or punishment. (p. 229)

Moreover, the 'optional' nature of ISL experiences, where people need to be motivated to attend, engage, and reengage over time, make understanding motivation in such settings a particularly important question (Falk & Dierking, 2000). Some authors have even raised the point as a necessity or 'demand' of successful communication in leisure settings: 'interpretation must be entertaining and interesting since external incentives for audiences to pay attention (e.g., exams, grades, etc.) do not exist in leisure settings' (Ham, 1994, p. 108).

In line with this, Csikszentmihalyi and Hermanson (1999) argue that experiences in ISL settings are fundamentally intrinsically motivated, 'Museums, without external means to compel a visitor's attention, must rely almost exclusively on intrinsic rewards. How then, can intrinsic rewards be made a part of the museum experience?' (p. 148). People attend museums, science shows and other ISL settings primarily due to positive qualities of the experience itself, rather than for external rewards (that is not to say, however, that the latter are absent).

> Action is extrinsically motivated when the anticipated rewards come from outside the activity. In this case, performance is simply a means to some other end – to obtain praise or to avoid punishment, to get a degree, or to live up to societal expectations. A person acts for the sake of intrinsic rewards when the performance itself is worth doing for its own sake, even in the absence of external rewards. Usually we are motivated by both extrinsic and intrinsic rewards at the same time. (ibid., p. 147)

In trying to better understand intrinsic motivation and value aspects in formal learning, Brophy (1999) poses a similar problem, though his example of a book could just as easily be a science show:

> We know much less about motivation in potential learning situations that do not involve seeking to achieve explicitly delineated goals. When engaged in primarily intrinsically motivated activities (e.g. when reading a self-selected book related to one's interests), expanding or deepening one's learning may be an implicit goal, along with other goals such as experiencing pleasure, appreciating the author's artistry, [etc.]. However, one is not studying to prepare for a test or reach some mastery criterion, so this is not an achievement situation (as usually defined). We need more attention to these potential learning situations that involve lifelong or at least sustained engagement in particular interest areas, which often lead to the development of expertise. (p. 75)

This perspective of non-achievement oriented motivational theories provides a focus on which theories are most important in a science show context. Key to these are theories growing out of intrinsic motivation. So what kind of motivation is involved in a learning activity where people engage just for the sake of the activity itself? In his later

discussions of value aspects of motivation, Brophy (2008) stresses that to answer such questions researchers must give 'attention to the learners' beliefs and feelings about the content, as well as the processes involved in learning and applying it' (p. 132). He notes three families of motivation theories that are the foundation of much of the research in this area: expectancy-value, interest and intrinsic motivation. These three motivational theories suggest fruitful avenues for understanding motivation in a science show context, however interest theories in particular appear to be the keystone, as argued below. Note that interest here refers to a motivational variable, and not the basic emotion discussed later (see discussion in section 2.5.1.).

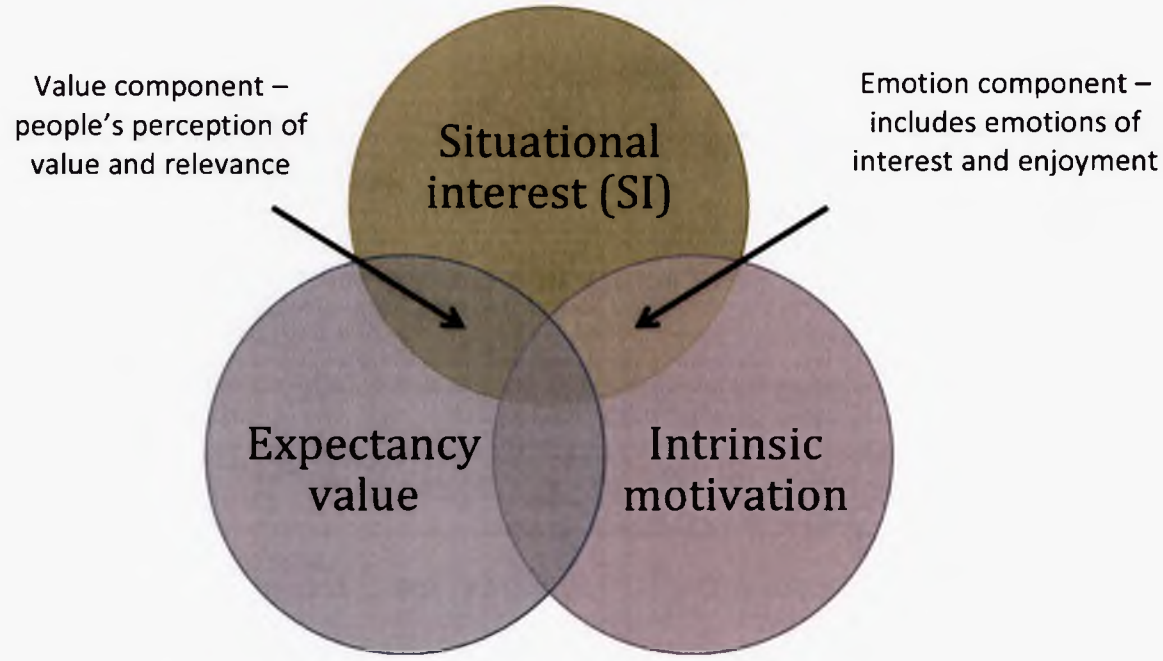

Figure 1. Overlap of motivational theories including situational interest (SI), intrinsic motivation and expectancy value.

Looking at the components of these theories in a science show context highlights which aspects are most relevant and important. Intrinsic motivation theories posit that intrinsic motivation is increased by the emotions of interest and enjoyment (positive emotions) during a task, along with having autonomy and control in choosing and

doing the task; it is not externally coerced (Deci, 1975; Deci & Ryan, 1985; Vansteenkiste, Lens, & Deci, 2006). Attending a science show is typically free-choice, and the show itself is primarily guided by the presenter (although interactive), hence autonomy and control are less relevant factors. Expectancy-value theories suggest that motivation for engaging in a task by choice is a combination of how much one values the activity and the expectancies of success (i.e. confidence). In the non-achievement oriented setting of a science show where it is difficult to 'fail', expectancies of success are less important.

Taken together, when considering intrinsic motivation and expectancy-value theories within the context of a science show, the key components are emotion (specifically interest and enjoyment) and value. These two components, along with knowledge, form the major components of situational interest (SI) – hence its suitability to apply to science shows. Moreover, recent qualitative studies have used SI as a model to better understand affect and motivation in other ISL settings (Dohn, 2011a, 2011b). Hence, the following sections on motivation will focus on SI, in particular its components of value and emotion – two features likely to be motivational in a science show.

2.2.2. Distinguishing motivation to attend and motivation resulting from a show

This thesis ultimately aims to understand what facilities motivation from science shows. While the above arguments largely focus on which motivational variables drive someone to attend a free-choice science show or to actively engage during it – largely intrinsic motives – it does not necessarily follow that motivational outcomes from the show (i.e. changes in attitudes or intended behaviour) will solely be caused by these variables. It does seem reasonable, however, to hypothesise that the same variables that motivate attendance before and engagement during the show will also have some

role in motivation following the show. As outlined in the rest of this chapter, formal learning supports this hypothesis, and the non-achievement setting of a science show makes it even more likely. While extrinsic factors are also involved in motivating outcomes from a science show and have been considered, they are out of scope of this work, in line with the arguments presented above.

2.2.3. Situational interest (SI)

Typically, educational psychology views interest as an emotional-motivational state (in contrast to the basic emotion view described elsewhere) based on the interaction between a person and an object. In this context, Hidi (2006) defines interest as follows.

> I consider interest to be a unique motivational variable, as well as a psychological state that occurs during interactions between persons and their objects of interest, and is characterized by increased attention, concentration and affect. The term interest also refers to a relatively enduring predisposition to re-engage with particular content such as objects, events and ideas. (p. 70)

The literature can be divided into two related areas on the person-object interaction, the first investigating longer-term person aspects, such as individual differences and development of enduring interest, termed *individual interest*. The second investigates shorter-term object aspects such as the sources of interest, termed *situational interest* (SI; Deci, 1992; Hidi, 1990), which is a focus in this thesis. While individual interest is beyond the scope of this research, it does share similarities with motivation in that individual interest describes an enduring disposition to engage with a domain, while motivation seeks to understand what affects that engagement. Most interest theorists,

including all those cited here, agree that interest in a domain like science develops from situational into individual interest.

Compared to formal learning, SI research is scarce in informal settings. Given the beneficial insights of applying SI in formal learning, this lack of understanding in informal settings is problematic. Moreover, ISL providers generally aim to create experiences that will foster interest development (i.e. situational to individual interest), yet understand little about the beginning of this process. Three recent studies have, however, used exploratory qualitative methods to determine sources of SI in ISL settings (Dohn, 2011a, 2011b) and science shows (McCrory, 2010), which will be discussed in the relevant sections below.

Hidi and Renninger's (2006) four-phase model of interest development divides SI into two phases: triggered and maintained. The other two phases describe individual interest which is beyond the scope of this research. The model suggests triggered SI is short-term and primarily based on attention and positive emotion (sometimes termed 'affect' or 'feeling' – 'emotion' will be used in this work), however the longer-term experience of maintained SI requires individuals to find personal value or meaningfulness in the content in addition to emotional arousal (Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000; Mitchell, 1993). Both triggered and maintained SI have been shown to operate over the duration of a school lesson (Mitchell, 1993), hence it is likely a similar process occurs during a science show.

The model also suggests that each phase of interest development involves varying amounts of emotion, value and knowledge, which is generally consistent with other interest theories (Hidi & Renninger, 2006; Krapp, 2007). Emotion and value play a greater role during SI, while stored knowledge features more during individual

interest. Some theorists have, however, on occasions downplayed the role of knowledge as an aspect of interest and motivation and not considered it an essential characteristic (Krapp, 2000). Given this thesis is not focused on cognitive learning, I will concentrate on SI's value and emotion components. Factor analysis has established that these emotion and value components are distinct but related components of SI in academic settings (Linnenbrink-Garcia et al., 2010), however no studies have established this in informal learning settings.

The following sections will explore the two components of SI most relevant to this work – value and emotion – and also discuss their role in other motivational theories.

2.3. Value as a motivational variable

When an experience or information has value it matters to an individual; it may be useful, applicable to a goal, link to their prior knowledge or experiences, or be important or meaningful for other reasons. In this thesis, I use the term 'value' to be consistent with educational psychology and museum studies, however the construct is often referred to as 'relevance' or 'meaningfulness'. In this section, these three terms are used more or less interchangeably depending on the terminology used in the research being discussed. A similar term 'contextualised' generally refers to information being placed in a real-world situation.

Value is a key component of both expectancy value and SI motivational theories. Most importantly, value is associated with maintaining interest, however its role in the transition from short-term SI to enduring individual interest is contentious (Hidi & Renninger, 2006; Linnenbrink-Garcia et al., 2010; Mitchell, 1993). This suggests that value during a science show should be associated with sustained-SI, however its

effects on motivational outcomes (which are similar to individual interest) are less clear. While some research has looked at the motivational outcomes of value in formal learning settings, this is virtually unstudied in ISL settings.

2.3.1. Value in formal and informal learning

In science learning settings, value is typically illustrated by showing science's connection: (1) broadly to everyday life; (2) to the general interests of students; or (3) to the specific lives of individual students. As the amount of individual specificity increases (1-3), the positive effects of value also appear to increase, as will be shown below. Formal education research on these three levels of specificity is reviewed below.

Recent research from Hulleman and Harackiewicz (2009) gives an elegant demonstration of the power of highlighting value directly to individual student's lives – the third and highest level of specificity. High-school students studying various semester-long science classes followed standard assignments by either (1) writing an essay on how what they had learnt linked to their everyday life, or (2) a summary essay of the material (designed as a control). Students wrote 4.7 essays on average. Those in the value condition who linked school learning to their lives felt more interest in science at the end of the semester, which predicted interest in further science study and courses, and achieved better grades by nearly two-thirds of a letter grade. These outcomes, however, only occurred in students with low expectations of success; high expectation students were unaffected. This is an important result as it shows that for low expectation students, solely thinking and writing about how what they learnt related to their lives was enough to substantially improve interest, motivational outcomes and grades, in isolation from any other relevance strategy (e.g.

incorporating links to student's lives into content), or other modifications to the teaching approach. These findings have been replicated in undergraduates in math and psychology, where a similar intervention increased the content's value, SI, and maintained interest in further study (Hulleman, Godes, Hendricks, & Harackiewicz, 2010).

Other studies also show that the more specifically value is tied to the individual (their life as opposed to life in general), the more powerful its effects on learning and intrinsic motivation – including interest and enjoyment (Cordova & Lepper, 1996). This study found that when learning is embedded in the same general real-world context, greater motivational effects were experienced when it was also personalised to participants than when it was not (ibid.). This shows that individually specific value has an additive effect on top of broad efforts to highlight value through real-world contexts. In these studies, value is tied to the *unique* prior knowledge and experience of the individual (which will be discussed further below). This highly personal form of value appears to be more powerful than general approaches.

Strategies working at the second level of specificity aim to make content valuable through general alignment to students' individual interests (hobbies or interests). These strategies try to place learning in the overlap between students' interests, everyday life and the desired learning outcomes – to some extent they generalise students as a group rather than individuals. Tailoring content this way both increases learning and is preferred by students (Choi & Song, 1996). Other studies found similar results, with increased 'contextualising' of content by students correlated ($r = 0.61$, $p = 0.05$) with increased learning, and contextualisation explaining 37% of the variance in learning gains (Rivet & Krajcik, 2008). Amongst the authors' criteria for contextualising

science learning were: linking to student individual interests and everyday life (in effect, making valuable); having a problem to solve requiring the information (highlighting usefulness or utility – a component of task value, see below); and, an anchoring event that could be part of instruction and/or a prior experience.

Initiatives to highlight value at the second level of specificity often tie value to demographic groups, for example, interventions tailoring high school physics content to the specific interests of females and males increased learning during the course (Hoffmann, 2002). Increased learning persisted into 'traditional' courses the following year, however for females this only occurred when the initial course highlighting gender-specific value was combined with partial female-only classes. This intervention also incorporated teacher style changes and single/mixed gender classes making exact effects of value somewhat unclear, however the overall focus was on gender-relevant content.

The third level of specificity is linking content broadly to everyday life, as opposed to student's lives and general interests (notwithstanding the overlap of these). This approach appears to be less powerful still. A meta-analysis of 17 studies which made links to everyday life and society, often termed 'context-based' or 'science-technology-society' approaches, found only limited evidence they were more effective for learning than traditional approaches (Bennett, Lubben, & Hogarth, 2006). Turning to attitudes toward science, the same meta-analysis found very strong evidence that – when compared to traditional approaches – science-technology-society approaches promote more positive attitudes to school science, limited evidence they promote more positive attitudes to science generally, and mixed though positive evidence on encouraging further science study.

Comparing this meta-analysis to Hulleman and Harackiewicz's (2009) intervention, it appears making general links to real-world contexts is less powerful for learning and motivation than making specific links to student's lives. This underscores the advantages of highlighting value that relates specifically to the individual. However, given this is impractical in a diverse science show audience, tying content to unique collective demographic attributes (such as local geography, events or personalities) should be more powerful than general links to the wider world – both of which are used in science shows.

Research also addresses why value aids learning, suggesting that it is a combination of cognitive factors – e.g. providing scaffolding and anchor points to build knowledge – and motivational factors – e.g. making learning more engaging and increasing motivation to learn (Linn, 2000; Rivet & Krajcik, 2008). Malone and Lepper's (1987) taxonomy of intrinsic motivations for learning stresses these motivational aspects, noting that when learning goals are personally meaningful they will be maximally motivating. They divide relevance (value) into instrumental relevance, where utility is stressed, and fantasy relevance, where learning is embedded contexts familiar or appealing to students. Empirical studies comparing motivational strategies used by teachers support these motivational effects on students. Relevance strategies – where teachers highlighted the importance and value of content and/or students were encouraged to relate tasks to personal experience – were most highly correlated ($r = 0.607$) with, and the best predictor of, student on-task behaviour – a sound measure of motivation (Newby, 1991).

Value also facilitates motivation and affects decisions beyond the learning experience, which underscores its significance in this thesis. For example, studies investigating the

perceived importance (value) of mathematics found it was the best predictor of future enrolment intentions (although not grades) with authors emphasising the 'critical role (especially for girls) that value perceptions play in determining students' intentions to enroll in advanced mathematics courses' (Meece, Wigfield, & Eccles, 1990, p. 69). These intentions translated into actual decisions to continue studying mathematics (Wigfield & Eccles, 2000). Similar positive influences on future studies and careers were also found in studies reviewed above (Hulleman et al., 2010; Hulleman & Harackiewicz, 2009). Taken together, in formal learning value is a powerful influence on learning outcomes, fosters motivation to learn, and motivates decisions to continue learning.

The effects of value are, however, relatively unstudied in informal contexts. ISL and science show research, somewhat surprisingly, focuses little on value and linking content to people's everyday lives. This is possibly because value is an implied feature of many ISL experiences and anecdotally touted as a good feature, or may just reflect the comparatively small amount of research in informal settings. While no research has been found dealing with value's motivational impact in science shows, a few authors have noted its importance and encouraged making links to everyday life (Gouniyal, 2007; Sadler, 2004) or using everyday items and contexts (Gore, 2009). In research comparing learning from two different shows, Gouniyal (2007) concluded:

> Science theatre may be enhanced by offering value based, application oriented science for reflection rather than presenting impersonal, decontextualised, theory. A narrative, story based presentation of real world applications of science facilitates greater connection building and reflection, leading to more effective and insightful learning. (p. 3)

In his discussion of key features of interpretation, Ham (1994) argues relevant information is more interesting and understandable, more deeply encoded and hence better remembered, and more easily perceived and processed. He also underscores the links between value and prior experience and prior knowledge, noting 'the relevance of a message appears to be strongly influenced by the recipient's background' (ibid., p. 110) and suggesting successful interpretation should tie to common experiences of the audience to command greater attention (the second level of value specificity). These effects of value, as well as its links to emotion, are noted by numerous ISL researchers, for example Dierking (2005).

> Memorable experiences ... were not about learning some fascinating factoid of science. Instead, the experiences shared often included a close interaction with an object or idea of personal significance to the participant, which was described in a rich and emotional way. (p. 111)

Bitgood's (2006, 2010) attention-value model of museum visitors is the only in-depth treatment of value so far by ISL researchers. The crux of the model is that for museum visitors the perceived value of an exhibit will be its potential utility (relevance) divided by the costs to the visitor, such as time, effort and money (Bitgood, 2010). In line with the phases in SI theories, Bitgood argues that perceived value is the critical element to 'capture, focus and engage' attention, that is, grab attention and then maintain it for a significant interaction. While the model suggests value is critical in motivating engagement during a museum visit, it does not deal with motivational outcomes from the visit.

In summary, value is widely considered to be an important feature to aid learning and motivate in both formal and informal learning settings, including science shows.

Showing people the value and relevance of content aids motivation to learn and provides scaffolding for cognitive learning in the short-term, and in the longer-term influences behaviour such as future study choices. Formal learning research suggests the positive impacts of value increase the more specifically it is tied to the individual. The least specific first level of value simply places science content in real-world contexts. In the second level, value can be made more specific by selecting contexts thought to be appealing to the audience – a technique regularly used by teachers and show presenters. In the most specific third level of value, people make their own personal value judgments about how content links to their lives – this is ultimately how people decide value.

2.3.2. How prior knowledge and prior experience influence value

What people judge as valuable will be heavily influenced by what they already know and have done in the past. Indeed, the strategies used for highlighting value (such as relating content specifically to an individual or more generally to everyday life) rely on placing content in a context where it can be understood in terms of a person's prior experience and prior knowledge (PEPK). Discussions of value in informal settings often implicitly involve PEPK, as noted as far back as the 1950s.

> Any interpretation that does not somehow relate what is being displayed or described to something within the personality or experience of the visitor will be sterile. (Tilden, 1957, p. 9)

Numerous formal and informal learning studies have investigated how PEPK influences learning, understanding or other cognitive measures, however its relation to value and motivation is less explored. Prior knowledge is a central feature in theories of conceptual change (e.g. Posner, Strike, Hewson, & Gertzog, 1982), cognitive conflict

(e.g. J. Nussbaum & Novick, 1982) and constructivist learning (e.g. Baviskar et al., 2009; Yager, 1991). Informal learning researchers have also stressed PEPK, as highlighted by Falk and Dierking's (2000) reflections on a decade of research.

> Hundreds of people have shared their museum memories with us, and in virtually all cases, prior knowledge figured prominently in their recollections. (p. 26-27)

They go on to discuss that in informal learning environments, recall is stronger when content is linked to prior knowledge rather than being completely novel, that learning may also take the form of reinforcing prior knowledge (linking this to constructivist assimilation), and that prior knowledge and learning are inherently linked to context – which again ties back to valuing. Similarly, Stocklmayer and Gilbert (2002) found that prior experience is the foundation upon which understanding of a science centre exhibit is constructed, and this operates by people being reminded of prior experiences. Further, they propose a model of 'personal awareness of science and technology' (PAST) that suggests prior experiences, through 'remindings', are a key feature of the way people understand scientific concepts.

Relevant to this thesis is ISL research drawing links between prior knowledge, learning and prior attitudes in the context of environmental behaviour. Falk and Adelman (2003) extend the arguments about prior knowledge being involved with understanding to also include attitudes, arguing, like others, from a constructivist viewpoint.

> The creation of new understandings and attitudes depends on the successful integration of the learner's prior experiences with new experiences afforded by the physical and

> sociocultural context of, for example, an aquarium visit. (p. 164).

This supports the view that prior experience will influence not only changes in knowledge, but also attitudes – the two are interrelated. Consistent with this, in the study, prior environmental attitudes (termed 'interest/concern') – informed by experiences – were a critical factor in environmental knowledge gain. Individuals with minimal to moderate prior environmental attitudes had the greatest gains in knowledge. The study did not, however, look at the role of prior attitudes on attitude or motivation change.

Taken together, these studies suggest PEPK influences value and is key to understanding and knowledge gain in ISL settings. Questions, however, remain regarding PEPK's relation to value (which has not been established quantitatively in ISL settings), and whether PEPK can be a directly motivational feature.

2.3.3. Value as an element in motivational models

Value is a key component of both SI and expectancy-value motivational theories, however value theorists have done more to unpack the concept. Expectancy-value theories of motivation (Eccles, 1983; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000) propose that expectancies (i.e. confidence) and value lead to motivation. The value of a particular situation, such as a science show or school class, is described as a task value. In Eccles' (1983) model, task value is divided into four components, (1) utility value – the task's relevance for achieving goals or other life activities, (2) attainment value – the task's importance to the individual in relation to their self-concept and identity, (3) cost value – negative aspects of the task such as how it affects other choices or creates negative states like anxiety, and (4) intrinsic value – the interest and

enjoyment the task provokes, which is effectively the emotion 'feeling' component of SI. There is wide evidence that utility and intrinsic task values are of most importance in formal learning settings (cf. Hulleman et al., 2010). Eccles' components of value start to highlight ways in which people may judge value, however during this review no research was found directly investigating how people judge the value of science (although the question is often tangentially answered).

Intriguingly for this research, in formal learning research that included motivation towards 'leisure' or free-choice activities, intrinsic value but not utility and attainment values (which were combined in the study) predicted free-choice activities, whereas utility and attainment values predicted career goals (both predicted further school study; Durik, Vida, & Eccles, 2006). This suggests intrinsic value, which is extremely similar to the emotion component of SI (interest and enjoyment), should motivate reengaging in free-choice settings, however utility and attainment value should motivate other aims of some free-choice settings such as promoting careers and other more concrete outcomes. Testing this hypothesis could allow fine-tuning of the types of value that need to be highlighted to achieve different aims in ISL settings.

Value is a particularly important motivational variable as it is implicated in longer-term interest and interest development. Value is a distinct component of maintained-SI and this has been verified in numerous formal learning settings (Hidi & Renninger, 2006; Linnenbrink-Garcia et al., 2010; Mitchell, 1993). Value is also argued to be an important aspect of encouraging lifelong learning (McCombs, 1991). Hence value appears important for holding people's interest over time, however its role in developing individual interest is less clear.

Hidi and Renninger's (2006) 4-phase model argues that value is critical for the development of SI into individual interest. They argue that each phase of interest development involves changes in stored emotion, knowledge and value; describing the interaction of these components as 'affect [emotion] is identified as an integral part of interest engagement; together with knowledge, it is considered to inform valuing' (p. 118). One interpretation of this is that emotion and knowledge in combination influence value, making value the endpoint, and hence make it the critical factor for both SI and development into individual interest. Linnenbrink-Garcia and colleagues (2010) argue a similar point:

> Maintained-SI provides the link between triggered-SI and individual interest. Once students hone in on the course material (triggered-SI), those who view it as enjoyable and meaningful (maintained-SI) are likely to value the material beyond the context of that particular course and may seek out new opportunities to have contact with the domain and expand their knowledge. It is through this transformation of maintained-SI that individual interest is thought to develop. (p. 649)

The empirical research, however, that has addressed this issue suggests emotion and not value may influence individual interest. Linnenbrink-Garcia and colleagues (2010) found that SI as a whole significantly predicted changes to individual interest. Although when different sub-factors (components) of SI were regressed on changes to individual interest, emotion sub-factors (triggered-SI and maintained-SI-feeling, which describe short- and long-term emotional responses) predicted changes to individual interest, however the value sub-factor was not a significant predictor. The authors note these results may be domain specific (the study was in mathematics), and that value aspects

of interest may develop more slowly than emotion aspects as value is something that is perceived over time. As individual interest has similarities to what is described in this thesis as motivational outcomes, investigating the relative effects of emotion and value is an important question.

In sum, value is a key component of several motivational models including SI. Although value is agreed as a key motivator, there is little structured knowledge of how people make judgments of the value of science. This lack of knowledge is more problematic in ISL settings where, in the absence of extrinsic rewards, value is likely to play a major role as a motivator. Theorists have, however, divided value into four components – utility value, attainment/identity value, cost value, and intrinsic value (or positive emotion, as discussed below) – which provide general guidelines for how value is perceived. Intrinsic value is thought to motivate engagement in free-choice activities, while utility and attainment values motivate outcomes from free-choice activities such as encouraging future study. Within interest development models, value is argued by several theorists to be more critical as it: (1) is responsible for holding interest or sustained SI; (2) is the end-point for other influencing factors such as emotion and knowledge; and (3) facilitates the transition from situational to individual interest. Empirical data to support this third conclusion is limited, with one study suggesting that emotion and not value played a larger role in developing individual interest in mathematics. In general, the relative role of value and emotion as components of SI is somewhat unclear, as is their precise role in fostering different sorts of motivational outcomes. This is particularly true in ISL settings where no quantitative research has been conducted.

2.4. Emotion as a motivational variable

Emotion is a critical motivator (Deckers, 2010), hence its study in motivation research and inclusion alongside value in SI models. The words emotion and motivation share the same Latin root *emovere*, which means 'to move out'. This association was noted by Descartes (1649/1989) who argued, 'the principal effect of all the passions [emotions] in men is that they incite and dispose their soul to will the things for which they prepare the body' (p. 40-41). Indeed, one of the fundamental roles of emotions is to prime us to take action; each emotion readies us for a specific set of actions that accompany it, termed action-tendencies (Frijda, 1986). Hence emotions are a fundamental source of motivation (Deckers, 2010), meaning particular emotions are likely to be motivational features within science shows. Emotion, often termed feeling or affect, is a central component in SI and intrinsic motivation. These motivational models will be discussed, followed by unpacking the components of emotion.

2.4.1. Emotion in SI

SI models suggest an ongoing role for emotion through the different phases of interest development, however it is most dominant in earlier phases, whereas in later phases other factors such as value play a greater role. According to Hidi and Renninger (2006):

> Affect [emotion] may be used as an indicator of interest because it is an affective response that initially triggers a person's attention and because knowledge may only be minimal. If a situational interest is to be maintained, however, a person's feelings and stored valuing need to lead to reengagement over time. (p. 120)

SI models are limited in explaining the precise nature of the emotional experience. Emotion research is rarely incorporated into SI models; most studies do not distinguish

SI from the emotion of interest, nor consider emotions individually. An approach integrating SI models with emotion psychology could extend the depth and precision of SI models by treating the emotion component as a combination of several basic emotions (individual fundamental emotions, discussed further in section 2.4.3.). This would allow more targeted measurement and manipulation of emotion and hence SI.

SI models do, however, give some indication of the basic emotions that form the emotion component of SI, and hence may be motivational features of a science show. SI involves positive emotion, however it may also involve negative emotion (Hidi & Harackiewicz, 2000; Iran-Nejad, 1987), which is also true of the valence of the emotion of interest (Silvia, 2006; Turner Jr. & Silvia, 2006). While SI models rarely discuss basic emotions, interest and enjoyment (and synonyms such as fun) are commonly mentioned as describing the emotional aspects of SI and reviewing survey items used to measure SI confirms this (Chen, Darst, & Pangrazi, 2001; Linnenbrink-Garcia et al., 2010). Interest and enjoyment also feature in qualitative SI research used in ISL settings and science shows (Dohn, 2011a; McCrory, 2010).

The role of the emotion of surprise in SI is less clear. ISL, science show and general SI researchers claim surprise is a source of SI (Dohn, 2011a, 2011b; Iran-Nejad, 1987; Iran-Nejad & Cecil, 1992; McCrory, 2010), however other research suggests surprise leads to or is associated with curiosity (Ainley, 1986, 1998; Charlesworth, 1964, 1969), as discussed in section 3.1.. The comparative role of different emotions, especially surprise, in generating SI is unclear.

2.4.2. Emotion in intrinsic motivation

The emotions involved in intrinsic motivation overlap greatly with those of SI. Numerous theorists propose that emotion, in particular the combination of the basic emotions of interest and enjoyment, is central to intrinsic motivation (Deci & Ryan, 1985; Reeve, 1989). The concept of flow (Csikszentmihalyi, 1975, 1990), which could be described as a pure or extreme form of intrinsic motivation, also includes interest and especially enjoyment. During intrinsic motivation, interest and enjoyment are widely proposed to work together in sequence, interest directing attention to a particular object/activity and enjoyment being derived from engaging with the object/activity. Reeve (1989), drawing on several previous studies, sums up the interaction.

> Interest... contributes to intrinsically motivated behaviour by arousing attention, attracting curiosity, and inviting exploration, investigation and manipulation of the stimulus. Enjoyment, on the other hand, ... contributes to intrinsically motivated behaviour by encouraging future encounters with the activity and by increasing one's willingness to seek out and conquer task challenges. (p. 101)

Interest and enjoyment often occur in a positive emotion tandem or cycle (Izard, 1977; Izard & Ackerman, 2000). This cycle can be reciprocal and drives repetitive behaviour (Izard, 1977) and, significantly for ISL settings, typifies developmental processes in children's play (Izard & Ackerman, 2000).

Taken together, the emotional aspects of both intrinsic motivation and SI, in learning settings and everyday life, are dominated by interest and enjoyment. This conclusion provides support for interest and enjoyment being motivational features of a science

show, however has only been arrived at from the motivational literature. The following sections explore the issue from the perspective of the emotion literature.

2.4.3. Basic emotion models

Major theoretical models of emotion can be divided into dimensional or basic emotion models. Dimensional models (e.g. Watson & Tellegen, 1985) structure emotion across a number of dimensions, most commonly valence (i.e. pleasantness-unpleasantness or positive-negative) and arousal/activation (i.e. level of activation or high-low intensity). Emotional states are then described by their placement on the two dimensions, for example contentment is a pleasant, low-intensity state. In contrast, basic emotion models categorise and define discrete 'basic' emotions based on distinct characteristics, such as antecedents, behavioural responses, facial expressions, physiological effects, underlying appraisals/components, and unique evolutionary and adaptive purposes (Ekman, 1992, 1999; Izard, 1977). On face value, basic and dimensional approaches seem inconsistent, however studies have shown that they can be reconciled by viewing them as describing varying levels of specificity. For example, Tellegen, Watson, and Clark (1999) showed the structure of emotion can be described hierarchically, first with a happiness-unhappiness dimension at the highest level, then with positive and negative activation dimensions below that, and finally with basic emotions at the base level.

Hence, basic emotion models represent the most specific way of organising and differentiating emotions. This suggests they are the most appropriate model for this research given the aim is to identify particular motivational features. Basic emotion models provide a sound foundation on which to unpack the emotional component of

SI and in turn the motivational features of science shows. To unpack these emotions, I turn to another product of basic emotion and dimensional models: appraisal theories.

2.4.4. Appraisal theories of emotion

Appraisal theory, in essence, breaks each basic emotion into a series of appraisals or checks – judgment steps from the individual's point of view to assess which emotional response is generated in response to a stimulus. For example, when an event is appraised as (1) inconsistent with one's motives/goals, and (2) caused by someone else, the emotion of anger is generated, whereas if it was self-caused, then regret is generated (Roseman, 2001; Roseman, Antoniou, & Jose, 1996). Appraisal models can be thought of as empirically tested definitions of an emotion's precursors, components or fundamental sources, hence offer potential for precise research investigating emotions during a science show.

Appraisal theory can be utilised to address the often conflicting and vague definitions of emotions given in other areas of psychology and ISL research. Moreover, viewing emotions in terms of their appraisals may provide more targeted ways to evoke these emotions through a science show. Indeed, appraisal theorists have highlighted how better manipulating appraisals can influence emotions and emotional behaviour, even singling out educators as a group who may employ such strategies (Roseman, 2001). Roseman goes on to point out that scholars as far back as Aristotle proposed emotion-appraisal type concepts 'to help orators create emotions in an audience so as to influence their behaviour' (ibid., p. 82). The direct relevance to this thesis is startling.

One advantage of appraisal theories is that because appraisals are a subjective judgment they offer an explanation of why different people experience different

emotions when faced with the same stimuli (Lazarus, 1991). The emotion is a quality of the person's interpretation of the stimulus, not the stimulus itself (ibid.). Appraisal theorists have criticised educational psychology's SI model because it does not adequately explain individual differences in what is interesting, which the subjective judgment in appraisal theories of interest neatly addresses (Silvia & Kashdan, 2009). These critiques are somewhat flawed as they do not discuss the role of individual interest or value judgments – ideas central to SI that address individual differences in what is interesting. While both appraisal and educational psychology camps critique each other, little has been done to integrate their ideas for a more holistic understanding.

In sum, appraisal theory appears to be a useful tool to address often conflicting and vague definitions of emotions, as well as provide more depth and precision in their measurement (including within models such as SI). In other fields attempting to unpack the emotional experiences of real world situations, such as the arts and aesthetics, the efficacy of appraisal theories has been demonstrated (Silvia, 2005; Silvia & Berg, 2011). This is a promising lead for ISL emotion research.

2.4.5. Which emotions are important in science shows?

Which emotions are most promising for influencing motivation from a science show when all emotions motivate some kind of action? The lack of science show emotion research means the answer to this question can only be arrived at indirectly. To answer this question I will review which basic emotions are important in life and learning settings, then overlay that with which emotions occur during science shows and the scarce literature concerning this. Finally, I will contrast conclusions of which

emotions are critical with those drawn from motivational models, which suggest interest and enjoyment and to a lesser extent surprise are important.

Although not the dominant model of emotions used in this thesis, dimensional models offer a good starting point in refining emotions of importance. Fundamentally, demonstration-based science shows as studied in this work aim to provide a positive experience for audiences. While some negative emotions such as fear may be inadvertently activated, the vast majority of emotions stimulated during a science show are positive. Using negative emotions, even in cases where they may be effective (e.g. actively using fear to motivate behaviour from an HIV AIDS show), is ethically problematic, especially in young audiences. No shows in this study aimed to create negative emotions, in fact in those where they were likely (climate change and HIV AIDS) show content was designed to mitigate any such negative feelings. Moreover, fear-based strategies have been shown to be ineffective for engagement with emotive scientific issues such as climate change (O'Neill & Nicholson-Cole, 2009). For these reasons, along with others below, beginning with a focus on positive rather than negative emotions is a good starting point.

2.4.6. Positive emotions

Historically, psychology has been more interested in the negative than the positive when investigating the human psyche; an approach that until recently has dominated studies of emotions in general (Fredrickson, 1998) and within learning environments (Pekrun, Goetz, Titz, & Perry, 2002a). The last two decades, however, have seen an explosion of research into wellbeing and happiness – termed 'positive psychology' – and along with it a wealth of new knowledge on the benefits of positive emotions. Experiencing frequent positive emotions, especially relative to negative emotions, is

important for people to function optimally or 'flourish' (Fredrickson & Losada, 2005) and also a key component which contributes to overall wellbeing (Seligman, 2011).

While emotion theorists disagree on which positive emotions qualify as basic emotions or emotions at all, the emotions of interest and enjoyment/joy feature prominently in many established models. Izard (2007) argues that of the positive emotions, only interest and joy/happiness qualify for inclusion as the most basic emotions, which she argues are natural kinds (a fundamental product of nature). Izard's (1977) earlier lists also include surprise, which in itself has no valance and can be positive or negative depending on subsequent emotions. Fredrickson's broaden-and-build model of positive emotions (Fredrickson, 1998, 2001, 2004) includes interest, love, enjoyment/joy and contentment. Importantly for the motivational reaction to a science show, the broaden-and-build model posits that positive emotions broaden both the scope of attention and an individual's 'thought-action repertoires' – in other words, what the emotion causes people to think about and do. The model suggests that a science show fostering positive emotions should not only make people pay attention to a wider range of stimuli in the show, but also be more open to thinking about and acting on these stimuli. This is an important factor for any science show hoping to motivate people.

Of the positive emotions discussed above, some are not relevant to a science show experience such as love; it is emotions such as interest and enjoyment that are more likely to be of importance. This focus is further supported by the fact that both interest and enjoyment are classified as activating emotions as opposed to deactivating emotions (Watson, Wiese, & Vaidya, 1999). For example, enjoyment is an activating

emotion as it typically promotes action, whereas contentment is a deactivating emotion as the action it promotes is in fact inaction.

Positive emotions have a raft of beneficial effects, however those around decision making and thinking processes are most relevant to this research. Work by Isen and colleagues (for a review see, Isen, 2000) shows positive emotion (they use the term 'affect') facilitates improved decision making; it fosters efficiency and thoroughness in deciding between options and helps people think more creatively and flexibly. In a science show aiming to change how people think – to motivate them – these effects of positive emotions should be beneficial. In line with Fredrickson's more recent broaden-and-build model, and highlighting enjoyable situations like ISL settings, Isen concludes:

> All else being equal, positive affect tends to promote exploration and enjoyment of new ideas and possibilities, and new ways of looking at things – especially in enjoyable or 'safe' situations. Therefore, people who are feeling good may be alert to possibilities, may explore and play, and may solve problems both more efficiently and more thoroughly. (Isen, 2000, p. 431)

Not surprisingly given these findings, positive emotions have an important role to play in any learning environment. As to which emotions are most critical, the positive emotion literature reviewed above suggests interest and enjoyment are of critical importance. These two emotions are also central to SI and intrinsic motivation, as discussed in sections 2.4.1. and 2.4.2..

2.4.7. Positive emotions in formal and informal learning

Emotions are critical to learning, engagement and motivation, especially in free-choice or ISL environments which are less achievement-oriented than formal school-based

learning. Research in the formal learning sector has demonstrated positive emotions including interest and enjoyment have a wide range of beneficial effects on school and tertiary education (Pekrun, Goetz, Titz, & Perry, 2002a). Within science education in particular, research suggests that 'affect', of which emotions are a large part, increases student engagement and learning (Alsop, 2005). Emotions influence the student-teacher relationship (Maria, Santos, & Mortimer, 2003) and several researchers have advocated for more emotional engagement in science teaching (Alsop, 2001; Alsop & Watts, 2003; Zembylas, 2005).

Despite the evident importance of emotions in science learning, our understanding of how they operate in ISL settings is limited. ISL researchers have, however, highlighted the importance of emotions, often arguing that positive emotional experiences are critical to encourage ongoing engagement and longer term outcomes such as attitude and behaviour change (Ballantyne & Packer, 2005; Ballantyne, Packer, Hughes, & Dierking, 2007; Csikszentmihalyi & Hermanson, 1999; Falk & Dierking, 2000; Falk & Gillespie, 2009; Howard, 1999; Smith, 2008). Moreover, some have argued informal settings may be more suitable than formal settings to study affect, as affect is more critical in free-choice intrinsically motivated settings (Dierking, 2005). These arguments within the formal and informal education community echo a larger movement within psychology which contests the traditional divides between cognition and affect are not valid, and that affect is a key aspect of cognitive learning, how people make decisions and behave (Immordino-Yang & Damasio, 2007).

The small body of ISL emotion literature can be divided into two areas: first, that investigating emotions purely as outcomes of an experience, and second, that investigating emotions themselves – which is rare. Recently, emotional responses have

been incorporated as indicators in two widely used models for assessing learning in informal environments: the Generic Learning Outcomes used in the United Kingdom, which notes enjoyment/fun and surprise (Museums Libraries and Archives Council, 2008), and the Six Strands Framework used in the United States, which notes interest and curiosity (National Research Council, 2009; Shouse, Lewenstein, & Feder, 2010). (Curiosity will be discussed in detail in section 3.1.). Adoption of these indicators has led to a range of research and evaluation projects measuring emotions (e.g. Hann, 2008; Lim, 2007; Rivett, 2009; Tuah, 2009).

While incorporating emotions as indicators of learning is a positive step, it also means measuring them effectively is more critical. In almost all science show and most ISL research, however, quantitative measurement of emotions is typically via single questions and qualitative measurement often collapses several similar but distinct terms into single categories. This approach lacks both accuracy and precision. This observation is corroborated by research reporting ISL practitioners (and researchers) do not immediately differentiate between emotion terms and often use them haphazardly (Meredith, Fortner, & Mullins, 1997), and ISL lacks a clear lexicon and definitions for different emotions.

> [ISL] practitioners interviewed made little apparent discrimination between the phenomena of interest, curiosity, attention, and enjoyment until probe questions were pursued. (p. 816)

Problems of accuracy and precision are not limited to ISL. Opening their seminal review on intrinsic motivation in formal learning, Malone and Lepper (1987, p. 229) note 'we use the words fun, interesting, captivating, enjoyable, and intrinsically motivating all more or less interchangeably' which at least they are aware of and have

stated, which is often not the case in ISL research. This once again raises problems around terminology and precision.

Recent ISL research has begun to address issues of depth and precision in emotion measurement. Falk and Gillespie (2009), in some of the scarce research focusing on emotion in ISL settings, used a modified version of Russel's Affect Grid which separates and rates affect over two perpendicular dimensions (pleasant feelings – unpleasant feelings / high arousal – low arousal). The grid also noted relaxation, stress, depression and excitement as different combinations of the two dimensions, for example, excitement is high arousal/pleasant feelings and depression is low arousal/unpleasant feelings. This approach is useful as: (1) it adds depth by viewing emotion as having underlying dimensions such as arousal and pleasantness; and (2) it adds precision by nominating an emotional state (e.g. excitement) that results from a combination of these dimensions.

While the treatment of the emotional experience within ISL as broad dimensions such as arousal/pleasantness is an improvement to precision, it also has limitations. Dimensional measures of emotional measurement are less favoured and were moved on from by many emotion researchers around the turn of the century (Ekman, 1992, 1999). Using dimensional models also restricts ISL emotion research from capitalising on the wide body of basic emotion literature. This is particularly problematic when basic emotions are used as indicators of learning in informal settings. One potential candidate to address issues in precision is a basic emotions approach, which views emotions as distinct units rather than collectively and provides rigorously defined terms and a common lexicon for emotions.

A basic emotions approach to address precision in turn leads to opportunities to address depth. Depth, as discussed here, relates to unpacking the individual emotions and understanding their components and sources. As appraisal theories are built on basic emotion models, they provide an ideal avenue to add depth. Appraisals, in one sense, can be thought of as the fundamental components or sources of an emotion. Investigation of not only distinct basic emotions, but also the appraisals that generate them in ISL settings can improve precision and depth. It may also allow practitioners the ability to manipulate emotions via their appraisals, giving a more targeted way to foster different emotions.

In summary, ISL and science show research leaves room for further depth and precision in emotion measurement. The importance of this is highlighted by the increasing focus on emotion in formal learning, especially in the area of science. Moreover, widespread use of emotions – particularly interest, enjoyment and to a lesser extent surprise – as learning indicators underscores the need to understand their operation in detail. How can emotional responses be valid indicators of learning if the underlying knowledge of them in ISL settings is minimal? Investigation of basic emotions and unpacking their components using appraisal theory, improving both precision and depth, is one way to address this issue.

2.4.8. Emotion research in science shows

Typically, emotions are reported as audience responses to science shows; knowledge of how they operate and what causes them is extremely shallow. Reporting of interest and enjoyment responses has increased recently due to their inclusion in the Generalised Learning Outcomes. Much of this research also reports emotional responses in combined categories, making interpretation difficult. These studies do

however provide useful information. They demonstrate that interest, enjoyment and to a lesser extent surprise and curiosity are regularly reported outcomes of science shows, and that they are cited as reasons for beneficial effects. In open-ended responses, interest and enjoyment (categorised along with fun, funny and exciting) are the top two emotions associated with beneficial outcomes, comprising 16% to 48% of responses about wanting to attend again, and 5% to 20% of what they will tell a friend (Caleon & Subramaniam, 2007; Tuah, 2009).

Other science show studies provide more depth on the effects and operation of emotions. Gouniyal (2007) reported that interest was associated with Q&A sessions, a common form of interactivity; enjoyment was associated with family social interactions; and surprise could be in response to either demonstrations or spoken content, however these conclusions were drawn on limited qualitative comments. Wyles (2010) provides data on the differences between interest and enjoyment – a problem that has also vexed psychologists. She found scientific concepts and abstract knowledge (e.g. forces) were noted as interesting, however not enjoyable. This is in line with interest's greater cognitive aspect when compared to enjoyment. In contrast, enjoyment rather than interest was experienced due to interactivity (5:1 enjoyable to interesting) and the presenter (only noted as enjoyable). Despite these differences, when simply comparing levels of interest and enjoyment they correlated highly ($r = 0.63$, significance not reported) leading Wyles to conclude that the audience did not highly differentiate the two. It should be noted that Wyles' research did not set out to methodically measure interest or enjoyment, nor to try to distinguish them.

Other show research has categorised demonstrations into five types with one category having strong links to surprise (Sadler, 2004). Critically, Sadler found that

demonstrations with a counterintuitive element – those that have a surprising outcome which is initially somewhat puzzling and fosters curiosity – had the greatest 'impact', measured both by recall of audiences and consensus of professional presenters. Surprise's role more generally will be explored in the following sections, and its links to curiosity discussed in section 3.1.3..

Paul McCrory's PhD research is the only thorough work investigating emotions in science shows. McCrory interviewed 23 expert ISL and science show practitioners about emotional engagement techniques found in the literature and his own experience, extracting data on a range of specific emotions, emotion-related constructs (e.g. beauty) and emotional engagement tools (e.g. demonstrations and props). These emotional engagement techniques, he argues, are ways of generating SI in science learning environments – this is the crux of McCrory's research. He then went on to design a course to enable schoolteachers to use the emotional engagement techniques. McCrory discusses in detail the basic emotion of surprise and the motivational variable of curiosity, both of which he identifies as sources of SI. He also discusses several other show characteristics investigated here (e.g. humour), which will be discussed later. McCrory's research provides a rich science show specific resource for the current work, laying a qualitative foundation for the largely quantitative techniques employed here.

2.4.9. Summary of critical emotions during a science show

A review of the literature on emotions in motivational models, learning settings, and science shows points to three basic emotions most worthy of investigation: interest, enjoyment and surprise. These emotions occupy the common ground between which emotions are most critical in life, learning and science shows. Moreover, while formal

learning and ISL researchers stress their importance, understanding of them in ISL settings is limited. Perhaps most critically, informal learning researchers have chosen these emotions – particularly interest and enjoyment – as indicators of broader forms of learning. This underscores their role as potential motivational features and the need to understand them fully. These emotions and their appraisals will be discussed in the following sections.

2.5. Interest, enjoyment and surprise

2.5.1. Interest

Before discussing the emotion of interest, it is critical to first note that 'interest' is used in slightly different contexts by different areas of psychology. This research incorporates both emotion and educational psychology research, which surprisingly rarely draw on each other's literature. To reconcile these somewhat disparate literatures, this thesis views the emotion of interest as part of SI, namely part of the emotion component along with enjoyment. This view is supported by: scales used to measure SI and its emotion component ('SI-feeling'; Linnenbrink-Garcia et al., 2010); arguments that variables that provoke interest sit in a larger subset that provoke SI (Ainley, Hidi, & Berndorff, 2002; Hidi, 1990; Hidi & Anderson, 1992; Silvia, 2005b, 2006); arguments that complex SI sources can be collapsed and simplified into interest's appraisals (Silvia, 2006); and that other emotions like surprise (Iran-Nejad, 1987; Iran-Nejad & Cecil, 1992) and enjoyment (Chen et al., 2001) are also argued to be sources and/or part of SI.

Interest is the emotion associated with exploration and information-seeking (Fredrickson, 1998; Izard & Ackerman, 2000; Silvia, 2005b). Interest finds mention over a century ago amongst luminaries like Dewey (1913) and Darwin (1872), then research

on it was sidelined by behaviourist psychology and a focus on negative emotions until the late 20th century, where it has been intensively researched (Silvia, 2006). Although some emotion researchers debate whether interest is an emotion, a debate not reviewed here, there are sound arguments to view it as such (cf. Silvia, 2006, 2008).

Izard (1977) describes interest as 'a feeling of wanting to investigate, become involved, or extend or expand the self by incorporating new information and having new experiences with the person or object that has stimulated the interest' (p. 216). More recently, Izard argues for an even greater role for interest – that it is *the* omnipresent emotion that steers attention and hence leads to all new emotions, cognitions and ultimately motivations.

> The emotion of interest or a succeeding emotion or pattern of emotions that it helps generate is the principle force in organizing consciousness...In most circumstances free of stress or threat, interest is most likely to be the emotion in the human mind that continually influences mental processes. (Izard, 2007, p. 271)

Fredrickson (2001) defines interest as an impulse to explore. Using her thought-action repertoire structure, she argues interest involves feelings (thought) of being 'animated and enlivened' and leads to behaviour (action) to increase knowledge and experience. This points to interest's key role in learning, especially in informal settings as highlighted by Silvia (2006).

> People who must create feelings of interest – entertainers, teachers, writers, artists, magicians, and beleaguered babysitters, to name a few – need to now how to manipulate the emotions of other people. This requires understanding the dynamics of emotional experience. (p. 31)

Interest can have both positive and negative valence, however is more often associated with pleasant feelings (Ellsworth & Smith, 1988; Turner Jr. & Silvia, 2006). During ISL experiences interest is likely to be positive, however 'gross science' or, relevant to this work, shows on HIV AIDS may be examples where interest's valence varies.

Interest, whether defined as an emotion or SI, is important in learning and education and leads to increased attention, cognitive functioning, recall, grades, effort, persistence and deeper information processing (Ainley, 2006; Ainley, Corrigan, & Richardson, 2005; Dewey, 1913; Ellsworth & Smith, 1988; Hidi, 2001, 2006; Hidi & Harackiewicz, 2000; Krapp, 2007; Silvia, 2006, 2008). While many of these outcomes are associated with other positive emotions such as enjoyment, interest has the greatest effects on effort and persistence, however some studies suggest these effects are only seen when psychological resources are depleted (Thoman, Smith, & Silvia, 2011). Hence, interest is argued to be an important emotion for replenishing emotional resources and building resilience (ibid.; Fredrickson, 2001). In sum, interest is a critical emotion in learning and life in general.

Interest's appraisals

Silvia (2005b) proposes that interest relies on two appraisals: (1) the novelty and complexity of the stimulus; and (2) the ability of the person to 'cope' with the stimulus (or understand it). While other appraisal models have proposed structures for interest, Silvia's model has fared best in experiments designed to test competing appraisal structures (Turner Jr., 2006; Turner Jr. & Silvia, 2006). Importantly, Silvia's research has verified the effects of interest and its appraisals in real-world contexts that parallel

science shows, including emotional responses to art and movies (Silvia, 2005a; Silvia & Berg, 2011).

The novelty-complexity appraisal is a check for a family of characteristics describing a stimulus including 'new, ambiguous, complex, obscure, uncertain, mysterious, contradictory, unexpected, or otherwise not understood' (Silvia, 2005b, p. 90). Research looking at other emotions appears to disagree with some inclusions such as the concept of schema-discrepancy (similar to 'contradictory') and unexpectedness being linked to surprise (Meyer, Niepel, Rudolf, & Schützwohl, 1991; Roseman, 2001). 'Mysterious' also has connotations to curiosity and information-gap type concepts, as reviewed in section 3.1.. This apparent disagreement stems from two main places; first, much emotion research focuses on single emotions in isolation, second, a stimulus may provoke multiple emotions concurrently or in sequence (e.g. surprise then interest).

There are many parts of a science show that may be assessed against the novelty-complexity appraisal. Regarding novelty, both demonstrations and concepts may be new to audiences, while complexity may be perceived at the demonstration level or through the overall complexity and variety presented in the show. Novelty and complexity are corroborated as sources of SI in the educational psychology literature (Ainley et al., 2002; Hidi, 1990; Hidi & Anderson, 1992), fitting the view adopted here that the emotion of interest can be considered part of SI.

Interest's second appraisal is coping potential (Silvia, 2005b). In emotion research, coping potential (and similar concepts under different names, i.e. 'power' or 'control potential' (Roseman, 2001)) appears in the appraisal structures of several emotions and refers generally to one's power, resources, capacities and control in relation to a

stimulus (Lazarus, 1991; Scherer, 2001; Silvia, 2005b). In interest, Silvia proposes coping potential refers to a person's perceived capability to comprehend, understand (or capacity to understand in time), or generally deal with a stimulus (Silvia, 2005b, 2006). In a science show, this could relate to understanding an individual demonstration or concept, or understanding how concepts relate in the show as a whole – these in turn rely on material being appropriately pitched for audiences. If a person can't 'cope' with a novel stimulus, rather than feeling interest they may be confused, frustrated or bored (uninterested).

Novelty/complexity and coping potential are the two appraisals or 'checks' that influence interest. Silvia (2005b) argues, and demonstrates, that a person will be most interested when they a stimulated with novel, complex information that they also feel able to cope with. This has been verified using both traditional lab-based psychological methods and, importantly for this research, using things like poems, film and art. In one particularly notable experiment, Silvia shows interest in abstract poems can be manipulated by providing background notes on what they are about – this manipulates coping potential and in turn interest. This idea has enlightening parallels to the role of a good explanation in a science show demonstration. By providing a well-pitched explanation the presenter increases the audiences' coping potential for comprehending the science, hence making the demonstration more interesting. Conversely, a poorly explained demonstration can confuse or frustrate instead of interest; while the stimulus may be novel and complex the presenter has not provided the background information for the audience to cope with it and hence interest is not aroused.

2.5.2. Enjoyment

Enjoyment or joy is the positive emotion related to the achievement of a goal, positive movement toward a goal or an event being consistent with one's motives (Power & Dalgleish, 2008; Roseman, 2001). This definition is also sums up the key appraisal for enjoyment, as discussed below. The importance of the goal is argued to determine the intensity of the enjoyment and major life goals are likely to provoke more than everyday enjoyment (Power & Dalgleish, 2008). Enjoyment is less researched than many other emotions so definitions are less clear; enjoyment research tends to have been overshadowed by enjoyment's relation to happiness. Happiness is argued to be a net representation of many goals in many domains, whereas enjoyment is specific to a particular goal in one domain (Power & Dalgleish, 2008). This point also highlights that it is enjoyment more than happiness that is likely to be aroused by a science show.

Enjoyment's goal relatedness means enjoyment of an ISL experience will depend on the individual's motives. Research shows that people come to ISL experiences with a wide range of motivations, often determined by the identity they assume (e.g. a parent), and these motivations affect how people learn and engage (Falk, 2006, 2009; Falk, Moussouri, & Coulson, 1998). So different people, due to their different motives, will enjoy different things during an ISL experience. For example, a parent may enjoy a science show because their child learns something (motive: provide an educational experience for my child), however the child may enjoy the same science show as it contains exciting demonstrations (motive: be entertained). This fact makes measuring underlying components of enjoyment somewhat more complex, but is critical in designing experiences that will be enjoyed by all.

Educational psychology research builds on and concurs with the emotion definitions of enjoyment given above. As enjoyment is such an everyday experience, however, it is not explicitly defined in educational psychology. The closest to a detailed definition comes by inspecting scales used to measure enjoyment. The Academic Emotions Questionnaire (AEQ; Pekrun, Goetz, & Perry, 2005; Pekrun, Goetz, Titz, & Perry, 2002b) measures enjoyment in learning environments with items that tap: (1) being excited; (2) being happy specifically about learning; (3) looking forward to learning; and (4) being motivated about learning. These aspects are consistent with the nature of enjoyment as discussed elsewhere. Point one highlights enjoyment's link to interest-like constructs such as excitement (the AEQ does not measure interest separately); point two shows the relation to happiness; point three is consistent with the idea that enjoyment is related to satisfying a goal; while point four shows enjoyment's role in motivation. Other models also place enjoyment as a forerunner to motivation, including flow and intrinsic motivation, as previously discussed.

Enjoyment is a frequently reported emotion in formal learning and has a range of beneficial effects on both the processes and outcomes of learning, however educational research on it is in its infancy compared with interest. Enjoyment focuses attention on the learning task and reduces distraction, fosters creativity and flexibility, improves problem solving, aids learning from mistakes, and aids self-regulation of learning (Goetz, Hall, Frenzel, & Pekrun, 2006; Pekrun, 2000; Pekrun, Goetz, Titz, & Perry, 2002a). Enjoyment is the most commonly reported positive emotion in university students, accounting for 40% of positive emotions and 14% of all emotions (Pekrun, Goetz, Titz, & Perry, 2002a). Enjoyment is more critical for learning processes rather than outcomes like grades (Laukenmann, 2003), suggesting it is important in ISL

settings where achievement outcomes are less relevant. It does, however, still have numerous positive effects on test results and final grades (for a review, see Pekrun, Goetz, Titz, & Perry, 2002a). In addition, Goetz and colleagues (2006) showed enjoyment has hierarchical effects on learning at various levels of generalisation (e.g. enjoyment of learning compared to enjoyment of specific learning activities). This suggests that if science shows affect enjoyment of science learning generally, this may influence enjoyment of classroom science learning – an effect anecdotally reported.

Enjoyment's appraisals

Enjoyment has a more fleshed out appraisal structure than interest as the majority of research concerning it is part of a holistic appraisal model describing several emotions. Roseman and colleagues' model, as described here, is the only one that incorporates enjoyment/joy (through not interest) as distinct from happiness, playfulness or other related positive emotions. Enjoyment's fundamental appraisal is that an event is consistent with a goal or motive (Power & Dalgleish, 2008; Roseman, 2001; Roseman, Spindel, & Jose, 1990). In addition, the goal is appetitive, that is, it presents a reward or positive development as opposed to avoiding a punishment or negative development – the latter criteria will instead elicit relief (Roseman et al., 1996). The event causing enjoyment is judged to be certain if it is in the future (uncertain will elicit hope instead), or may have already occurred (ibid.).

With regard to trying to measure these appraisals following a show, the ideas of goal relatedness and positive rewards are most relevant. The previously discussed issue of varied motives for ISL engagement makes measurement against specific goals problematic in straightforward quantitative research. Instead, more general items

tapping ideas like the show being good, fun, what one was hoping for can be employed.

2.5.3. Surprise

Surprise may not appear to be a critical response to a science show worthy of investigation, however its role in cognitive development, relation to other constructs such as curiosity, frequency in response to science demonstrations, and use as a learning indicator make it of note.

Surprise, put simply, is a response to an unexpected event. Unexpectedness is the key appraisal for surprise, as discussed below. What is unexpected for an individual depends greatly on prior knowledge and experiences – what people base expectations on – and this is where researchers have started to unpack the processes underlying surprise. Charlesworth (1969) uses the term 'misexpected' to capture the distinction that an event is not only unexpected, but also different to what someone thought would happen. This quality is at the core of a discrepant event, a particularly memorable type of science show demonstration (Sadler, 2004) that will be discussed in section 3.1.1..

Building on this, the psychoevolutionary model of surprise (Meyer & Reisenzein, 1997) argues that events are surprising when then deviate from a person's schema relevant to the event. Schemas are collections of knowledge around a given concept that could include information on events, objects, people, situations – whatever is relevant to the given schema (Mandler, 1984). A person is surprised when a new piece of information or event is sufficiently inconsistent with an existing schema (Charlesworth, 1969; Meyer & Reisenzein, 1997; Schützwohl, 1998). The surprising event can then result in

the revision of a schema, either by adding to an existing schema or creating a new or replacement schema. These two processes describe constructivist assimilation and accommodation, respectively (Charlesworth, 1969). Checking an event against a schema may be conscious or unconscious, however if the schema is inconsistent with results and is updated it is likely to be a conscious process (Mandler, 1984; Meyer & Niepel, 1994; Meyer & Reisenzein, 1997). It follows that if efforts have been made to consciously activate a schema – a technique used by science show presenters, for example in asking for a prediction – this is more likely to lead to schema revision. (Other ways presenters can manipulate schemas will be covered in Chapter 7). Evidently surprise plays a key role in modifying existing knowledge and hence learning. So surprise is more than a response to an unexpected event, it is a response to a schema-discrepant event, which may result in new knowledge.

Once schema-discrepancy is confirmed, surprise sets a process in motion involving: (1) interrupting current activities and focusing on the surprising event; (2) checking the relevance of the event for the person's well-being (which may involve comparison with goals and provoke other emotions such as enjoyment); (3) an assessment of actions that may need to be taken immediately or in future; and (4) exploration to discover the cause of the event and better understand it (Meyer & Reisenzein, 1997), or put another way, curiosity. The power of surprise to command attention and disrupt ongoing functions is highlighted by the fact that step one is 'hardwired' into our brains as humans have different neural systems for perception of unexpected and novel stimulus compared to everyday events which are directed by knowledge, goals and expectancies (M. Corbetta & Shulman, 2002).

Surprise works in conjunction and blends with other emotions and motivational states. Surprise itself has a neutral valance, but will become a positive or negative emotion depending on the emotion that follows it. Importantly, some researchers also argue that surprise amplifies or intensifies subsequent emotions and creates stronger memories (Charlesworth, 1969; Desai, 1939; Meyer & Niepel, 1994; Vanhamme, 2000). For example, combinations of surprise and interest or enjoyment create the more intense feeling of delight (Kumar, Olshavsky, & King, 2001; Oliver & Westbrook, 1993; Plutchik, 1991), and delight or positive surprise on its own is associated with satisfying experiences in non-learning free-choice settings (Vanhamme, 2000; Vanhamme & Snelders, 2001).

With regard to how surprise combines with other constructs discussed here, one is commonly surprised and then interested (Iran-Nejad & Cecil, 1992) or curious (Charlesworth, 1964, 1969). Both of these 'investigative' states aim to make sense of the surprising stimulus, however it is unclear exactly which is involved and to what degree. Intriguingly, in research on stories, high-surprise story endings were only rated as more interesting than low-surprise story endings when the incongruity was resolved (Iran-Nejad, 1987). Extrapolating this finding to a surprising demonstration suggests a surprising demonstration will only be more interesting when it is explained or the audience otherwise makes sense of it.

Surprise's appraisals

The key appraisal for surprise is unexpectedness (Roseman, 2001; Roseman et al., 1996), or more precisely that the event is not consistent with existing schema (Meyer & Reisenzein, 1997). A series of studies have ruled out appraisals including novelty, unfamiliarity and uncertainty (Roseman et al., 1996). Meyer and Reisenzein (1997) also

add a series of additional appraisals and/or 'processes', however in the context of a science show unexpectedness, schema-discrepancy and how this links to other constructs which analyse the cause of the surprising event (interest and/or curiosity), are most relevant.

2.6. Summary: motivational models, value and emotion

This review has so far identified several motivational features that may be operating during a science show. Reviewing a range of motivational theories suggests that in free-choice settings – the circumstances in most ISL environments – intrinsic motivators are most pertinent to understanding motivation. Intrinsic motivation is when people engage in an activity purely for positive aspects of the activity itself, as opposed to external rewards or coercion (extrinsic motivation). When people attend a museum or a family science show they are largely intrinsically motivated. Hence, this research will focus on intrinsic motivators, although it should be noted that motivation arising from an ISL experience might also be extrinsically motivated.

A focus on which intrinsic motivators are relevant to non-achievement settings such as science shows identifies SI as a key motivational model, along with its components of value and emotion. People perceive value when they judge content as important, meaningful and relevant to them; the more closely content links to the individual the greater the motivational effects of value. The motivational power of value increases as it moves from general nonspecific instances (simply placing science in a real-world context) to personal and specific instances (a person making the connection between the science and their individual world). Value is an important motivational feature as it is thought to aid interest development, sustain interest over time, and motivate outcomes from the experience.

Emotion, the second component of SI, is a fundamental motivator of human behaviour. Within SI, intrinsic motivation, and value models of motivation, the basic emotions of interest and enjoyment appear to be critical, however surprise also appears to be involved. It is unclear if surprise generates interest and SI or curiosity, as discussed further in the next chapter. The central role of interest and enjoyment and to a lesser extent surprise is corroborated by literature on positive emotions and emotions in learning settings. The emotion literature also yields two theoretical models useful for understanding emotion in science shows: basic emotion theories, which specify a set of discrete emotions, and appraisal theories, which set out a series of 'checks' or steps involved in generating each basic emotion.

In sum, the review up to here has identified SI as a useful model for understanding science show motivation. SI's two components of value and emotion (comprising interest, enjoyment and surprise) appear likely to be motivational features of science shows. I now move onto two additional motivational features that have links to these constructs and may be particularly relevant for motivation during science shows.

Chapter 3. Literature review 2: Curiosity, immediacy and science show motivation

This second part of the literature review discusses two more motivational features that may be particularly relevant to science shows: (1) curiosity, which is a key aspect of science show demonstrations, and also related to interest and surprise; and (2) immediacy and enthusiasm, which describe qualities that create rapport between presenter and audience. The unique nature of a science show as a live, presenter-audience experience using science demonstrations suggests these features may play a significant role. The chapter concludes with a review of the motivational impacts of science shows and refinement of the research questions.

3.1. Curiosity as a motivational variable

The literature on interest and especially surprise highlights another potential motivational feature within a science show: curiosity. Curiosity is often used synonymously with interest (i.e. Reeve, 1989), however some recent research suggests the two constructs are quite different. Despite the apparent importance of interest and curiosity, within learning settings the literature is still somewhat unclear how they differ. Curiosity is also cited as a source of SI and intrinsic motivation (Deci, 1992; Hidi & Harackiewicz, 2000). Curiosity is entwined with many of the constructs already earmarked as motivational, hence deserves further attention.

Curiosity, a desire to gain new knowledge and experiences from exploratory behaviour, has been described as the critical motive that influences human behaviour (Berlyne, 1960; Litman, 2005; Litman & Silvia, 2006; Loewenstein, 1994) as well as a powerful, memorable facet of a science show (McCrory, 2010; Sadler, 2004). Curiosity

is at the heart of learning and science, making it a likely motivational feature of a science show. Thinking on curiosity has a long tradition, Charles Darwin (1872/1998) discussed curiosity-like constructs he called perplexed meditation and stupefied amazement and noted they were a common response to surprising or puzzling phenomena across many cultures. Curiosity is not an emotion, rather can be defined as a 'positive emotional-motivational system associated with the recognition, pursuit, and self-regulation of novel and challenging opportunities' (Kashdan, Rose, & Fincham, 2004, p. 291). As this definition alludes, curiosity can be aroused by features of a stimulus termed collative variables (novelty, complexity, uncertainty and conflict), in particular conflict (Berlyne, 1954, 1960; Kashdan et al., 2004). Berlyne's concept of conflict – where two ideas or events seem inconsistent or can't be reconciled – has similarities to schema-discrepancy, highlighting the relationship between surprise and curiosity.

Curiosity has been shown to be a precursor of intrinsic motivation and flow experiences, both in everyday life and learning environments (Csikszentmihalyi, 1990; Deci, 1992; Deci & Ryan, 1985; Hidi & Harackiewicz, 2000; Malone & Lepper, 1987). This suggests people are self-driven and enjoy discovering new information when curious, which is paramount for effective learning – especially in informal settings. The importance of curiosity in informal settings is astutely captured in the foreword to Freeman Tilden's seminal work on interpretation.

> Anatole France said, "Do not try to satisfy your vanity by teaching a great many things. Awaken people's curiosity. It is enough to open minds; do not overload them. Put there just a spark. If there is some good inflammable stuff, it will catch fire." To excite curiosity, to open a person's mind – there is a

> challenge for anyone who seeks to communicate ideas. I know of no one more sensitive to the challenge than the interpreter... he works with people who are at leisure. (Hartzog, 1957, p. v)

It is, however, largely unknown how curiosity operates during ISL experiences and science shows, although given that science show research suggests it is a vital factor for engagement, and that demonstrations exhibiting curious qualities are most memorable (McCrory, 2010; Sadler, 2004), it may well be an important motivational feature.

3.1.1. Curiosity and discrepant events in formal in informal learning

Curiosity is widely acknowledged as a key part of learning and motivation to learn. Seminal educational researchers have argued that curiosity is a central part of child development and education (Day, 1982; Piaget, 1927), some even going as far as saying 'curiosity is the most direct intrinsic motivation for learning' (Malone & Lepper, 1987, p. 235). Within formal education research, curiosity is an understudied area, however studies on discrepant events and constructivist learning offer insights into its role.

A discrepant event is characterised by a surprising, unexpected result that is counterintuitive to the viewer and conflicts with existing knowledge (see also section 2.5.3.). In this thesis, discrepant events refer particularly to demonstrations with these qualities. A common theme argued in the education literature is that discrepant events provoke curiosity; the surprising, counterintuitive result triggers a powerful instinctive curiosity reaction that aids learning. Piaget noted this when looking at the understanding of causality in children, saying 'whatever contradicts this conception

provokes, by the mere fact of doing so, the maximum of curiosity on the part of the child' (Piaget, 1927; p. 275).

Discrepant events are widely used and studied across formal science education (Chin, 1992; Crawford, 2003; Freedman, 2000; Friedl, 1986; Tsai, 2000). Large collections of discrepant events for classroom use have been amassed, their use by teachers strongly encouraged (Liem, 1987), and they have been tailored to many topics such as chemistry, earth sciences, biology and physics (Wright & Govindarajan, 1995). Discrepant events are key to learning strategies based around conceptual change and conceptual conflict (Nussbaum & Novick, 1982; Posner et al., 1982) which laid the foundations for modern constructivist approaches. Constructivist theorists argue that discrepant events create cognitive dissonance, which aids accommodation and has been suggested as one of four essential criteria for constructivist teaching (Baviskar et al., 2009; Driver & Oldham, 1986; She, 2004; Tsai, 2000). Constructivist theory posits both dissonance generally and discrepant events lead to curiosity and, in turn, motivation to learn (Liem, 1987; Palmer, 2005; She, 2004). Liem (1987) sums up the significance of this in his collection of over 400 discrepant events for teachers.

> Once curiosity is aroused, the student will learn much more on his/her own than the teacher can ever teach him/her. Learning only takes place if the student wants to learn. The use of discrepant events in the teaching of science is one of the best methods ... to arouse interest and curiosity. (p. 7)

The wider context and what proceeds and follows the discrepant event is important for motivational and other outcomes. Used in isolation, motivation from discrepant events may only be short term (Hidi & Harackiewicz, 2000; Palmer, 2005), however when used as part of a broader model of instruction, sustained curiosity-fostered

motivation is often reported. This is illustrated by a physics teacher using a discrepant event strategy.

> I have taught the particle model for many years now and this is the first time all my students showed interest and enthusiasm. After these lessons they continued to wonder about the structure of air and came on their own during recesses to talk about it. They wanted to know more about the "correct" description and asked about new arguments they had thought of in the meantime. (Nussbaum & Novick, 1982, p. 197)

The above two quotes highlight two important gaps in the literature that may hinder curiosity's use in formal and informal learning. First, the causes, differences and relationship of curiosity and interest are unclear; this is an emerging area in psychology but virtually unstudied in educational settings. Second, that while provoking curiosity is a strong motivator of learning, research provides little detail on how or why this is the case. Current research on curiosity, as discussed in the next section, has the potential to explain both, yet has not been applied in educational settings.

Turning to ISL settings, researchers have argued curiosity is important for free-choice science learning, especially in providing motivation to engage (Falk, Storksdieck, & Dierking, 2007; Packer, 2006). Curiosity has recently been noted as an indicator of broad forms of learning in ISL settings as part of Strand 1 (along with interest and motivation) of the United States Six Strands Framework (National Research Council, 2009). It's importance has long been highlighted, in particular for shows and lectures, notably by physics Nobel Prize winner and science communication pioneer Sir Lawrence Bragg (1966):

> Here is a most important principle which I think of as the 'detective story' principle. It is a matter of order. How dull a detective story would be if the writer told you who did it in the first chapter and then gave you the clues. Yet how many lectures do exactly this. One wishes to give the audience the aesthetic pleasure of seeing how puzzling phenomena become crystal clear when one has the clue and thinks about them in the right way. So make sure the audience is first puzzled. (p. 1615)

Curiosity is a common audience response during science shows (Caleon & Subramaniam, 2007; Gouniyal, 2007; Tuah, 2009), however research to understand its nuances is less common. Within science shows, only one study has directly investigated the effects of discrepant events and curiosity, despite being widely used (most shows studied in this research involved discrepant events to some degree). Sadler's (2004) research on short- and long-term impacts (primarily memory) of shows established five categories of science demonstrations including a specific 'curiosity' category which broadly described discrepant events. The research found curiosity-type demonstrations were the most frequently recalled category immediately following a theatre presentation (33%) and in focus-groups 30 months later (25%); a similar pattern emerged from discussions with show presenters who cited curiosity-type demonstrations 50% of the time when asked which type have greatest impact. Sadler concluded:

> By looking at all the data available, it seems that by some considerable majority, demonstrations that are curious, novel, counterintuitive, or involve a challenge about the outcome, have most impact in the short and long term. (p. 50)

Along with categorising these demonstrations as curiosity-type, Sadler's description also notes counterintuition and challenge, which hints at a relationship between surprise, schema-discrepancy and curiosity during science demonstrations. Sadler's findings are echoed by another study by Anderson, Piscitelli, Weier, Everett and Tayler (2002) which investigated what children remember from museum and science centre visits.

> Children readily recalled and described at length their live, facilitator-led, lecture theatre-based programmatic experiences. Common to all of these experiences was a facilitated discussion featuring interesting or unusual subject matter. For example, at the science center, the "Unexpected Science" show presented several kinds of counterintuitive science demonstrations and engaging discussions. (p. 13)

While these studies suggest counterintuitive, curiosity-type content is better remembered, they do not speculate why, or if these memories have other lasting effects such as motivation – though it certainly supports the possibility.

In sum, curiosity is a key part of formal and informal science learning – especially science demonstrations – and is an important motivator in everyday life. These aspects make it a likely motivational feature within a science show. Our understanding of curiosity's role in ISL settings is limited, despite authors highlighting its general importance, and research showing it has a powerful impact during science shows. This thesis will address this issue by applying contemporary models of curiosity to science shows, especially with regards to discrepant events.

3.1.2. Information-gap and interest/deprivation models of curiosity

Recent research on curiosity builds on Berlyne's (1954) idea that some aspects of curiosity involve tension due to uncertainty or being deprived of information. Discrepant events provoke this aspect of curiosity. Two theories that have potential to explain the captivating curiosity of discrepant events include information-gap theory of curiosity (Loewenstein, 1994) and the more empirically established interest/deprivation (I/D) model of curiosity (Litman, 2008; Litman & Jimerson, 2004). The two theories are complementary though offer different insights, so will be used in tandem to explain the nature of curiosity and impact of discrepant events. Central to both theories is that uncertain or missing information can lead to feelings of curiosity that involve intrigue or tension – a state described as 'deprivation'. This is the type of curiosity one feels, for example, during a tense mystery story. It may also be provoked by science shows, in particular puzzling and counterintuitive discrepant events.

Information-gap theory 'views curiosity as arising when attention becomes focused on a gap in one's knowledge [which produces] a feeling of deprivation ... the curious individual is motivated to obtain the missing information to reduce or eliminate the feeling of deprivation' (Loewenstein, 1994, p. 87). Discrepant events rely on highlighting an information-gap through their result. Loewenstein argues curiosity will suddenly increase as a person focuses on the information-gap (e.g. by seeing a discrepant event result) then gradually increase as they close the information-gap (e.g. through understanding an explanation). This process may explain the high recall of discrepant events found by Sadler (2004).

Loewenstein also argues that one way to highlight an information-gap is to make people take a guess, such as forming a hypothesis, and then give them 'accuracy

feedback', in this context the result and explanation of the demonstration. This is common practice in science shows. He argues 'It is difficult to ignore or deny a gap in one's knowledge when one has guessed the answer to a question and been told [or shown] that it is wrong' (ibid., p. 91). He adds that making a guess exacerbates curiosity as the individual also wants to know if they are right and hence feel competent. Other research has demonstrated that guessing combined with accuracy feedback increased curiosity (Loewenstein, Adler, Behrens, & Gillis, 1992). Educational research parallels this result, where the effect of making 'hunches' was found to increase learning and search activity (curiosity) during inquiry based learning (Wilson & Koran Jr., 1976). Note that in stressing predictions Lowenstein emphasises the same point as educational theorists about highlighting assumptions and prior knowledge (e.g. Baviskar et al., 2009; Nussbaum & Novick, 1982). This adds weight to the approach of using information-gap theory to understand curiosity's role in discrepant events and curiosity.

A more recent theory has further developed Berlyne's and Loewenstein's ideas, proposing and testing a model that separates curiosity into two separate dimensions. Litman and colleagues (2008; 2004) separate curiosity into feeling-of-interest (I-) curiosity and feeling-of-deprivation (D-) curiosity, the latter of which has similarities to the concept of information-gaps. This model provides a robust way to differ interest and curiosity, something psychological research often overlooks, and is important in this thesis where the constructs are studied simultaneously. In essence, I-curiosity relates to things that it brings pleasure to find out; this has similarities to both SI and the emotions of interest and enjoyment. Conversely, D-curiosity relates to things that

are unpleasant or cause tension if not found out – such as a mysterious, unexpected demonstration result. Litman (2010) differentiates the two dimensions as follows.

> I-type curiosity reflects a relaxed and pleasant "take it or leave it" feeling towards new knowledge; acquiring new information is viewed as potentially pleasurable but not a necessity. When I-type curiosity is stimulated, situations characterized by uncertainty are viewed positively, and opportunities to resolve that uncertainty are regarded as potentially enjoyable. By contrast, D-type curiosity is an intense and uncomfortable "need to know" associated with moderately unpleasant feelings of tension or frustration. When D-type curiosity is activated, conditions characterized by uncertainty are viewed as increasingly bothersome; consequently, D-type curiosity motivates seeking specific, objectively correct and relevant knowledge in order to resolve the uncertainty. For D-type curiosity, acquiring new information is rewarding because it reduces negative feelings attributed to uncertainty. (p. 397-398)

Several empirical studies have provided evidence for the I/D model of curiosity, showing I- and D-curiosity are distinct but correlated types of curiosity (Litman, 2008; Litman & Jimerson, 2004; Litman & Silvia, 2006). Most of this research has been conducted on undergraduate psychology students, however one study has also verified it occurs in the general population too (Litman, Crowson, & Kolinski, 2010). These studies did not investigate I/D-curiosity's role or validity in learning settings (but did look at how it affects dispositions to learning).

Litman and colleagues' model is critical for the current work, as it gives an empirically supported way to differentiate interest and curiosity, as well as a theoretical framework to understand the impact of discrepant demonstrations. The ideas that

these two types of curiosity are operating during a science show, that they may have different effects on motivational outcomes, and that they may explain the memorable qualities of discrepant events will be developed throughout this thesis.

3.1.3. I/D models of curiosity and surprise

The relation of surprise to different motivational variables is contentious. On the one hand, surprise has been proposed as forerunner to interest (Iran-Nejad & Cecil, 1992), as a source of SI in ISL settings (Dohn, 2011a, 2011b) and an appraisal of interest (Silvia, 2005b). On the other hand, both empirical evidence and well supported arguments suggest surprise leads to curiosity (Charlesworth, 1964, 1969), though no recent research has explored this. Given the I/D model distinguishes I-curiosity (akin to emotional interest and SI) with D-curiosity, it may provide a way to resolve which motivational variable surprise acts on. People feel D-curiosity when they lack knowledge (schemas) to explain information or events, which, as discussed in section 2.5.3., is also at the core of why people experience surprise. Based on this, and the much earlier ideas of Charlesworth (1969), it is hypothesised – contrary to the majority of the literature – that surprise should act on D-curiosity, and not interest. No research has explored this connection.

3.1.4. Prior experience, prior knowledge, surprise and curiosity

As discussed in section 2.3.2., prior experience and prior knowledge (PEPK) appear to influence value, however it also has effects on surprise and curiosity. What is surprising is directly dependent on our existing schemas (knowledge structures), which are based on our PEPK (Charlesworth, 1969; Meyer & Niepel, 1994). In fact, some research on surprise uses this as part of the research method, building expectancy by repeating an event, that is, forming a schema based on prior experience, then

introducing a schema-discrepant event to generate surprise (e.g. Meyer, Niepel, Rudolf, & Schützwohl, 1991). (See also section 2.5.3.). Hence, if one is surprised by a demonstration – i.e. does not have the PEPK that explains which highlights an information-gap – then it follows that should lead to D-curiosity. Surprise is caused by schema-discrepancy (conflicting PEPK), whereas D-curiosity's role is to find appropriate schema (new experience or knowledge) to resolve the discrepancy. To my knowledge, no research has explored these proposed links between surprise and D-curiosity.

Information-gap and D-curiosity concepts infer a further role for PEPK, in that people can only be deprived of information if it isn't part of their PEPK. Moreover, for curiosity to be at its strongest, the information-gap must be large enough that the deprivation is felt, but not so large that it becomes overwhelming and the individual feels the gap cannot be closed, which may instead provoke confusion or similar feelings (Loewenstein, 1994). The size of the information-gap depends in part on the PEPK the person already has or that is provided by the presenter. Hence, PEPK should be related not only to what is valuable, but also to what is surprising and curious in a show.

3.1.5. D-curiosity and motivation

Paralleling the strong motivational outcomes of discrepant events, Berlyne's (1954) early theory and both recent theories propose deprivation results in more powerful motivation to seek information, compared to being curious solely for the pleasure of obtaining new information (Litman, 2005; Loewenstein, 1994). 'Information-seeking is motivated by the aversiveness of not possessing the information more than it is by the anticipation of pleasure from obtaining it' (Loewenstein, 1994, p. 92). In a discussion of the I/D model based on the neural systems that may underlie I/D distinctions, Litman

(2005) also argues that D-curiosity provides greater motivation to seek out information.

> Qualitative differences between I- and D-type curiosity – i.e., inducing interest or reducing tension, respectively – correspond to important quantitative differences in the extent to which they energize behavior; D-type curiosity is empirically associated with both more intense levels of reported state-curiosity and a greater degree of subsequent information-seeking behavior as compared to I-type curiosity. (Litman, 2010, p. 398)

This suggests demonstrations that primarily provoke surprise and D-curiosity, such as discrepant events, will result in more motivated search for explanation than demonstrations that primarily provoke I-curiosity, or interest and enjoyment.

Litman (2005) also draws links to *wanting* and *liking* neural systems which are involved in numerous motivational, appetitive and pleasure causing situations in humans and animals (Berridge, 1999; Berridge & Robinson, 1998). Liking is more associated with pleasure, whereas wanting is more associated with motivating approach behaviour and rewards (Berridge & Robinson, 1998). Litman argues that I-curiosity mainly activates liking, whereas D-curiosity involves activating both liking and wanting, creating more potent motivation.

These neurological arguments are backed up by other studies that have associated I-curiosity with intrinsic motivation and mastery learning goals, whereas D-curiosity is associated with both intrinsic and extrinsic motivation and mastery and performance goals (Litman, 2008; Litman et al., 2010). Litman concludes:

> These findings provided evidence that I-type [curiosity] is a fully intrinsic motive, in which learning is energized solely by the prospect of increased enjoyment, whereas D-type [curiosity] is an integrated motive that involves both personal pleasure but also concerns about objective performance. (Litman et al., 2010, p. 535)

These differing motivational effects of I-curiosity (in essence, interest and enjoyment, or the emotion dimension of SI) and D-curiosity have not been tested in ISL settings or, to the author's knowledge, in educational settings.

3.1.6. How educational psychology differs interest and curiosity

Educational psychologists investigating situational and individual interest have also discussed the relationship between interest and curiosity. Despite a relative lack of research, the most prominent view put forward is the similarity between trait curiosity (being curious as a disposition) and 'general individual interest', which describes more general curiosity-like aspects of individual interest as opposed to individual interest in a particular topic area. As the definition below demonstrates, general individual interest shares similarities with D-curiosity and information-gap views in that it involves a search to reduce uncertainty.

> General individual interest in learning is expressed as a desire to acquire new information, to find out about new objects, events, and ideas not restricted to any narrow domain. This may involve approaching and acquiring information about something novel or it may involve seeking new information concerning something the student already knows about. [It] represents a characteristic way of approaching novel, uncertain, or puzzling phenomena with the goal or purpose of

> understanding those phenomena. (Ainley, Hidi, & Berndorff, 2002, p. 546)

Ainley's (1987) research distinguishes curiosity into two scales, depth-of-interest curiosity and breadth-of-interest curiosity. Depth refers to investigating specific stimulus in order to understand them, whereas breadth refers to seeking varied and changing stimulus to experience what they are like. Other curiosity researchers have described similar dimensions of curiosity, using the terms specific (depth) and diversive (breadth) instead (Berlyne, 1960; Litman & Spielberger, 2003). Depth or specific curiosity is most likely activated as one tries to understand a science demonstration.

Significantly for this research, investigation of the basic emotions involved in depth-of-interest curiosity showed the most frequently reported were surprise, interest and enjoyment (Ainley, 1986). Ainley's research is significant as it provides a conceptual link between the concepts discussed in this thesis – the emotions of surprise, interest and enjoyment, SI, and curiosity – and the development of enduring individual interest; an avenue for further research.

Other interest researchers have also looked at the differences between interest and curiosity, with arguments centring on the ideas of Berlyne and other proto D-curiosity conceptualisations. Hidi and Anderson (1992) put forward three arguments that differ SI and curiosity. First, SI is aroused by many characteristics beyond the collative variables Berlyne proposed were most related to curiosity, namely uncertainty and conflict. Second, SI does not follow an inverted-U relationship between motivation and arousal, which Berlyne proposed for curiosity. Third, SI, in contrast to curiosity, cannot always be described as a question and is often sustained over a longer time, whereas curiosity is usually of a shorter duration and is resolved once the question has been

answered. Both the first and third arguments involve D-curiosity, information-gap conceptualisation of curiosity (despite being put prior to the emergence of these theories). While a body of research reviewed here supports the distinction between interest as an emotion, SI and curiosity, they are clearly related concepts. Indeed, interest researchers have called for more research investigating the interest-curiosity relationship, suggesting it may shed light on interest development processes (Krapp, Hidi, & Renninger, 1992).

3.1.7. Curiosity summed up

In sum, curiosity appears to be an important motivational feature for numerous reasons. Formal and informal learning both cite curiosity as a critical part of the learning process, particularly in facilitating motivation. This is especially true of science shows and demonstrations, where curiosity-evoking discrepant events are noted for their effectiveness and recall (Sadler, 2004). Recent curiosity theories provide a framework that differentiates interest and curiosity, which is vital when investigating them simultaneously. Litman's (2004) I/D model of curiosity divides curiosity into D-curiosity, which is about a search to resolve information-gaps and may involve feelings of intrigue and tension, and I-curiosity, which is more associated with interest, pleasure and enjoyment while receiving/seeking information. Research suggests that of the two, D-curiosity is a more powerful motivator of information-seeking. Along with links to interest, curiosity is also related to other constructs discussed here including PEPK and surprise, however the latter is often also linked to interest and SI.

In this thesis, the term 'curiosity' is conceptualised as D-curiosity, i.e. involving a search for missing information. In certain sections, for clarity, 'D-curiosity' will still be used to stress these aspects.

3.2. Enthusiasm and immediacy: a motivational feature for science shows?

Within a science show (classroom), the presenter (teacher) has a central role in facilitating motivation of the audience (students). While features like value may be motivational, they are communicated to the audience primarily through the presenter. Hence, qualities of the audience-presenter interaction may be directly motivational, or they may influence other motivational features. The following section reviews literature on teacher 'immediacy' – a term that describes various behaviours such as enthusiasm, humour and interactivity that build rapport between teacher and students and almost certainly play a similar role between show presenter and audience. In formal learning, enthusiasm and immediacy have motivational effects – often described as affective learning – however only one study has linked this to situational interest (Zahorik, 1996). This makes immediacy and enthusiasm likely, yet largely unexplored, candidates for being motivational features of a science show.

Immediacy is often associated with the use of humour and interactivity/involvement (making people feel part of an experience rather than removed observers). As these are key characteristics of science shows, especially those studied in this thesis, they will be discussed separately, however considered as a subset of immediacy.

3.2.1. Enthusiasm and immediacy in formal and informal learning

While known anecdotally to be critical, displaying enthusiasm is a factor that has received virtually no research in science show settings. McCrory's (2010) interviews with expert presenters are an exception, where he concluded that enthusiasm 'was often said to be the single most important factor for effective presentations' (ibid., p. 112). Studies also argue that it is important to have a likeable show presenter, and this

contributes to emotional engagement and learning (McCrory, 2010; Tuah, 2009). Behaviours that make one likeable have a close similarity to immediacy behaviours, which have received much research in formal learning.

Within formal learning 'teacher immediacy' describes verbal and nonverbal teacher behaviours which enhance closeness between teachers and students, promote interaction, increase sensory stimulation, encourage approach as opposed to avoidance behaviours, reduce the subjective physical or psychological distance between teachers and students, and reflect a positive view of students by the teacher (Andersen, 1979; Mehrabian, 1969, 1981; Witt, Wheeless, & Allen, 2004). Immediacy behaviours also tend to convey enthusiasm, so for the purposes of this discussion, I view enthusiasm being under the umbrella of immediacy.

Immediacy behaviours include things like using personal anecdotes, encouraging discussion and questions, humour, using student's names, talking to students outside/after class, using inclusive language (e.g. 'we', 'our'), providing constructive feedback, asking about students' feelings toward learning tasks, giving praise and encouragement, gestures, using tone and inflection when talking (not monotone), making eye contact, smiling, animated facial expressions and open body language (Gorham & Christophel, 1990). Studies indicate that for students (audiences) and the quality of teaching, enthusiasm for teaching (presenting) is more important than enthusiasm for subject matter (Kunter et al., 2008). In addition, absence of negative-immediacy behaviours (e.g. inexpressive delivery) is more influential than presence of positive-immediacy behaviours (Gorham & Christophel, 1990).

Enthusiasm and immediacy as a motivational variable

A meta-analysis of 81 studies found meaningful correlations between teacher immediacy behaviours, affective learning (defined as attitudes to the teacher and course and behavioural intention/motivation measures, including intention of future study), and perceived learning, but only very weak correlations with cognitive learning (Witt et al., 2004). It is important to note that affective learning as defined for this meta-analysis has significant overlap to what in this thesis is referred to as motivational outcomes. Correlations were generally consistent between verbal immediacy (affective learning, r = 0.49; perceived learning, r = 0.49; cognitive learning, r = 0.06) and non-verbal immediacy (affective learning, r = 0.49; perceived learning, r = 0.51; cognitive learning, r = 0.17). The meta-analysis also noted that several studies suggested teachers' verbal behaviours are mediated or overridden by their non-verbal behaviours.

Immediacy also increases motivation to enroll in similar classes in future and application of learning in everyday life (Andersen, Norton, & Nussbaum, 1981). Teacher immediacy has longitudinal effects over a semester on student state motivation (situational motivation to learn; not a trait or disposition), however changes are greatest in students with low initial motivation (Frymier, 1993). The same study found students' initial motivation predicted much more variance in motivation than immediacy (which has implications for studies using pre-post designs as used in this research). Taken together, in formal learning immediacy is associated foremost with affective learning and motivation, including effects on intention and behaviour. Hence, immediacy may play a similar role in science shows.

The majority of studies suggest that for learning outcomes, enthusiasm is mediated by emotional response, however it is unclear whether motivational outcomes are also mediated in this way. Some studies suggest immediacy leads directly to state motivation and this leads to cognitive learning (Christophel & Gorham, 1995); other research suggests affective learning is the mediating agent, that is, immediacy influences attitudes and intentions which influences cognitive learning (Rodríguez, Plax, & Kearney, 1996); still others suggest both affective learning and state motivation are at play (Christensen, 1998).

To more rigorously test this, Mottet and Beebe (2002) first established that emotional response measured dimensionally (pleasure, arousal, and dominance; not basic emotions) was significantly correlated to cognitive and affective learning, as was immediacy, with correlations ranging from 0.36 to 0.55. To try and demonstrate that emotional response was what linked immediacy and learning, they then regressed pleasure, arousal, dominance and immediacy on cognitive and then affective learning. In both cases, pleasure accounted for more variance than immediacy – 7% and 5% for affective learning, and 12% and 5% for cognitive learning, respectively (ibid.) – while arousal had a negligible role. One way to interpret this is that immediacy leads to pleasure which leads to learning. Although using a dimensional approach, pleasure is quite similar to the basic emotion of enjoyment and measured with items like happy-unhappy, while arousal has some similarities to interest. Hence, this study implicates an immediacy-enjoyment link.

Other qualitative studies investigating university lectures have, however, associated enthusiasm with SI, which combines interest and enjoyment (Tin, 2009). Within science show research, when people were asked what was interesting and enjoyable,

comments regarding enthusiasm or likeability of the presenter are all listed as enjoyable (Wyles, 2010). Taken together, these studies suggest that enjoyment is likely to be the main emotion aroused by immediacy and enthusiasm, however interest may also be aroused.

This conclusion is supported in research investigating enjoyment specifically, where enthusiasm was found to be positively correlated with enjoyment (Pekrun, Goetz, Titz, & Perry, 2002a) and moreover enjoyment was shown to transfer from teacher to student, and the transfer mediated by teacher enthusiasm (Frenzel, Goetz, Ludtke, Pekrun, & Sutton, 2009). Freznel and colleagues also argued that when a teacher (presenter) is enjoying teaching (a show), that enjoyment is exhibited as enthusiasm, citing evidence that the behavioural features of enjoyment and enthusiasm are very similar, e.g. smiling and widened eyes. Studies using qualitative phenomenographic or grounded-theory approaches have also found enjoyment of learning resulted from immediacy behaviours, including teacher encouragement, enthusiasm, interaction, positive feedback and asking questions (Ferris & Gerber, 1996). Unlike the bulk of studies discussed here, this research was carried out with mature age students, suggesting immediacy behaviours lead to enjoyment in a wide range of ages. Several other studies provide evidence for a link between immediacy and affect generally, including that immediacy will contribute to greater affect toward both the class/course and the instructor, and that it will lead to greater affect after a week's delay (Andersen et al., 1981; Titsworth, 2001).

Taken together, in formal learning immediacy and enthusiasm appear to act on emotions – particularly enjoyment but also interest – which then influence affective learning and motivational outcomes. Immediacy may, however, also have a direct

effect on motivation. Very little is known on enthusiasm and immediacy's effects in ISL settings, despite the key role human interactions play in these environments. The literature suggests a presenter immediacy – audience emotion – audience motivation relationship, which has not been tested in ISL settings.

Understanding the presenter immediacy – audience emotion relationship

A lethargically presented talk evokes the same in the audience – lethargy – whereas an enthusiastically presented talk helps makes the listener enthusiastic too. This idea is captured generally within social-cognitive learning theories (e.g. Bandura, 1986) that propose that people gain knowledge and are influenced through social interaction with others. More specifically explaining the presenter-audience transmission is the concept of emotional contagion (Hatfield, Cacioppo, & Rapson, 1993, 1994), which posits emotions can be transmitted and received from one person to another and sets out conditions for this. This transmission is as important in learning as it is in art, as noted by Tolstoy (1925/1898).

> To invoke in oneself a feeling which one has experienced and, having evoked it in oneself, then by means of movements, lines, colours, sounds, or forms expressed in words, so to transmit that feeling that others may experience the same feeling – this is the activity of art. (p. 173)

Evidence for transmission of emotions in learning situations is broad (Brophy & Good, 1986; Frenzel et al., 2009; Harris & Rosenthal, 2005; Mottet & Beebe, 2000; Titsworth, 2001; Witt et al., 2004). As noted, enjoyment has been shown to transfer from teacher to student and this transfer is mediated by teacher enthusiasm (Frenzel et al., 2009). Preconceptions the audience has about what motivates the presenter can also profoundly affect the audience-presenter transfer. In startling research conducted by

Wild, Enzle, and Hawkins (1992), teachers were portrayed to students as either extrinsically motivated ($25 payment condition) or intrinsically motivated (volunteer condition). The same teacher delivered the same lesson in both conditions and was unaware of which motivational condition had been portrayed to students. Despite this, students showed greater intrinsic motivation when taught by the teacher that students thought was volunteering (intrinsically motivated) and this flowed through into their interest and enjoyment.

> Students in the volunteer condition perceived the teacher as exhibiting greater enjoyment, enthusiasm, and innovation relative to those in the paid condition. They also enjoyed the lesson more, reported a more positive mood, and were more interested in further learning. During a free-play interval, students in the volunteer condition exhibited greater exploratory activity than those in the paid condition. (p. 245)

In sum, emotional contagion suggests the emotions and motivational states of show presenters, including how they are perceived or framed by audiences, may well provoke corresponding emotions and motivational states in audiences. Emotions are contagious, much the same as the old adage regarding laughter.

3.2.2. Humour in formal and informal learning

Humour, an immediacy behaviour, is commonly cited as an important feature of science shows by both science show presenters and audiences (McCrory, 2010; Peleg & Baram-Tsabari, 2011), however there is little research focusing on humour in ISL settings. It is anecdotally well known that audiences appreciate humour, and this is reflected empirically with 30% of people citing funniness as the top reason for liking a show in one study (Peleg & Baram-Tsabari, 2011) and in another 38.5% citing 'funny'

(grouped with 'fun' and 'enjoyable') as a reason to attend again (Tuah, 2009), which hints at humour's motivational potential. McCrory's (2010) interviews with show presenters also suggest that humour serves an important function in 'breaking the ice' and building rapport with the audience, highlighting immediacy aspects of humour. Other studies in planetariums have, however, suggested humour has a marginally negative effect on learning (M. S. Fisher, 1997), however some the humour used in this research may not have been appropriate for the adult audience

Humour is also researched in formal learning environments and is claimed to have a range of beneficial effects on learning and other aspects. Humour reduces negative emotions and boredom; aids student-teacher relationships; makes learning enjoyable; creates positive attitudes to learning; fosters interest and attention; improves comprehension, cognitive retention, and performance; and fosters creativity (Garner, 2006; Korobkin, 2011; Martin, 2007).

Research shows that for positive effects on learning and learning outcomes, humour needs to be used strategically – that is, sparingly and tied closely to key ideas – otherwise it may be counterproductive. In some of the most thorough research on using humour in teaching, Ziv (1988) compared 14 week courses taught with humour (including cartoons, anecdotes, and training for the lecturer) and non-humour approaches, but with the same content and lecturer in each. Students in the humour condition scored about 10% higher on final exams and the results were replicated across courses in statistics and psychology. Critically, humour was used sparingly and was tied to key concepts, i.e. used strategically, which Ziv argued was critical to the increased learning outcomes. The importance of strategic use is further highlighted by the way humorous content is remembered at the expense of non-humorous content,

meaning that if humour is not tied to key concepts but used haphazardly it is likely key concepts will be less well recalled (Martin, 2007). Martin (ibid.) sums the argument for strategic use succinctly:

> If teachers wish to use humour to facilitate students' learning of course material, they should ensure that the humour is closely tied to the course content. In addition, the constant use of humour throughout a lesson will have little effect on retention. Instead, humour should be used somewhat sparingly to illustrate important concepts and not peripheral material. (p. 356)

The type of humour is important; aggressive forms such as sarcasm and ridicule do not aid learning (Martin, 2007), while high proportions of self-deprecating and tendentious humour have negative effects on attitudes towards learning but not on attitudes towards the teacher (Gorham & Christophel, 1990).

Humour as a motivational variable

Humour can motivate learning and task involvement in formal education settings. Humour appears to be a less powerful influence on motivation than immediacy considered as a whole, with correlations between affective learning (attitudinal, motivational and intended behaviour measures) and immediacy three to four times higher than with humour (Gorham & Christophel, 1990).

In mathematics teaching, humour increased SI for students with low individual interest in mathematics, although slightly reduced SI for those with high individual interest (Matarazzo, Durik, & Delaney, 2010). The authors of this study suggested humour's motivational effects work by either increasing collative features such as novelty and incongruity (appraisals of interest) or increasing task enjoyment. Moreover, they

speculated humour might act on emotional interest by increasing the appraisal of coping potential (for a discussion of interest's appraisals, see section 2.5.1.). The effects of humour on interest were short-lived and appeared to work through the affective aspects of SI (ibid.). This evidence points to classroom humour acting on the emotions of interest and enjoyment, which may then contribute to SI and intrinsic motivation. This is supported by broader research, which suggests humour raises interest and results in enjoyment in a range of settings, however the emotion of surprise may also be involved as humour often relies on schema-discrepancy (Martin, 2007).

3.2.3. Interactivity in formal and informal learning

ISL environments place a high emphasis on interactivity; the common premising of 'interactive' before science centre or exhibit is but one example. Interactivity can be seen as an immediacy behaviour, as it serves to reduce distance and promote involvement between presenter and audience. Interactivity is a recurring theme in the small body of science show literature, highlighting its importance and wide use in shows. Examples of interactivity may be use of volunteers, Q&A sessions, dialogue and banter with the audience, Gedanken experiments (thought experiments the whole audience does) and so on. From this list, it is evident that interactivity may be physical or mental – in the latter case the term 'involvement' is sometimes used. Several science show researchers stress the need for interactivity, usually in the context of volunteers, Q&A and dialogue (Gouniyal, 2007; McCrory, 2010; Wyles, 2010). Other research comparing different types of demonstrations suggests that those involving volunteers are second only in impact (measured by recall) to counterintuitive demonstrations (Sadler, 2004).

Interactivity has also been shown to be an effective technique in formal learning. Interactive approaches to physics teaching resulted in increased problem-solving skills and cognitive gains two standard deviations higher than those from traditional approaches (Hake, 1998). Physical interactivity or 'hands-on' learning significantly increased science learning when included daily or weekly (Stohr-Hunt, 1996).

Interactivity as a motivational variable

Involvement is a similar concept to interactivity, however typically describes more internal processes within an individual – feeling part of an experience, or as Mitchell put it 'being an active participant in the learning process' (Mitchell, 1993, p. 428). The conceptualisation and measurement of involvement in Mitchell's study could just as easily be termed interactivity; two of the six scale items described hands-on interactive aspects, while the others related to interactive teaching styles as opposed to one-way lecturing. Mitchell (1993) found involvement is a 'hold' factor and contributed to maintained-SI – it sustained SI over a longer time – however the role of interactivity and involvement in SI has been little researched in detail since. A notable exception is that hands-on interaction with objects (albeit a constrained version of interactivity as described here) and social involvement are a source of SI in ISL settings (Dohn, 2011a, 2011b).

No science show research has explored interactivity in detail, however, like other immediacy behaviours, it has been associated with enjoyment (McIntyre, 1996, cited in Sadler, 2004) and to a lesser extent interest. When audiences were asked which parts of a show they found interesting and enjoyable, interactivity ('participation') was noted as enjoyable approximately five times more often than interesting (51 versus 10 instances; Wyles, 2010). The science show research discussed here suggests

interactivity is likely to primarily act on audience enjoyment (consistent with other forms of immediacy) which may then influence motivation.

Importantly, these studies show interactivity acts both on enjoyment, which is more associated with short-term affective aspects of triggered-SI, and is also a 'hold' factor associated with longer-term sustained-SI. In contrast to other immediacy behaviours, this suggests the motivational effects of interactivity go beyond arousing transient interest and enjoyment and may contribute to more sustained motivation.

3.2.4. Immediacy summed up

Immediacy describes a family of variables that build rapport and 'connection' between audience and presenter, or students and teacher. Characteristics of the presenter, such as being enthusiasm and likeable, and ways they present the show, such as using humour, interactivity and involvement, all contribute to immediacy. Immediacy fosters learning and has motivational effects including influencing attitudes and behavioural intentions (often described as affective learning). Research suggests that the motivational effects of immediacy are mediated by interest and/or enjoyment, which may then contribute to SI, although immediacy may also have a direct motivational effect. Immediacy's effect on interest and enjoyment may be explained by the concept of emotional contagion, whereby emotions transfer from one person to another, as a high-immediacy presenter tends to exhibit these emotions. Although immediacy – especially enthusiasm and interaction – is often touted as a vital part of a good science show, no research has explored its effects on motivation.

3.3. Motivational outcomes from ISL and science shows

The potential of ISL settings, especially science shows, to motivate people is a largely unexplored, yet promising area. This research divides motivational outcomes from shows into two categories, reflecting the different aims shows have. Shows may lead to *subtle motivational outcomes*, such as broadly influencing attitudes toward science or prompting people to seek further information, or *overt motivational outcomes*, such as specifically influencing intended behaviour with regards to health or the environment – however shows aiming for these kinds of outcomes are comparatively rare.

Subtle motivational outcomes

Studies demonstrate science shows can have positive effects of people's attitudes to science, which may include general dispositions toward science studies and careers. Although sometimes not stressed, these kinds of outcomes are implicit in most science shows. Shows in different countries (South Africa, UK and Singapore) focusing on different areas of science all had positive effects on attitudes toward science careers and 'enjoyment of science' (which included several motivational aspects like watching science TV or joining a science club), however had mixed results on highlighting the social implications of science (Caleon & Subramaniam, 2007; Gouniyal, 2007; Tuah, 2009). One observation from these studies is that the more concrete and specific the motivational outcome (i.e. specifying specific behaviours and times, as opposed to a general attitude), for example reading a science book during holidays, the less the positive effect. While authors speculated this may be due to contextual factors in a study of disadvantaged youth in South Africa who may not have access to books (Sunassee, Young, Sewry, Harrison, & Shallcross, unpublished manuscript), the same

result is seen in affluent audiences in the United Kingdom (Tuah, 2009) – both groups watched the same chemistry show. This suggests that concrete and specific outcomes – termed overt motivational outcomes here – are more difficult to influence.

While rare, studies have also found more tangible evidence of motivation, for example chemistry outreach shows were associated with increased applications and acceptances for chemistry at university, however effects were small and only in students who lived close to the university (Shaw, Harrison, Shallcross, Williams, & Shallcross, 2011). When considering motivation, how long effects last is also important. The only study to investigate changes to attitudes over time found that while cognitive gains from a show persisted after two weeks, attitudinal changes did not (Caleon & Subramaniam, 2007).

While useful, these studies have two major limitations. First, all but one used post-only measures of motivational outcomes, making it difficult to attribute changes to the show. It is reasonable to assume that audiences choosing to come to a science show already have favourable attitudes to science, indeed this is reflected in science show research (Bultitude & Eigenbrot, 2004), meaning change in attitude is the critical factor. Second, while it is clear science shows can motivate audiences, no research rigorously addressed which elements of the show facilitate this, making it difficult to speculate how shows can be better motivational tools.

Overt motivational outcomes

Overt motivation is ultimately about influencing specific decisions and behaviour change, which is a less common aim in ISL settings, especially science shows. Due to difficulties with measuring actual behaviour, especially around controversial issues,

most research looking at overt motivational outcomes focuses on how participants intend to behave. Behavioural intentions describe a person's plan to behave in a certain way (Nieswandt, 2005) and can include both planning to engage in positive behaviours or avoid negative behaviours. Behavioural intentions are often the focus of studies as they are the end point for other influencing factors in models that predict behaviour (Ajzen, 1991; Fishbein, Triandis, Kanfer, Becker, & Middlestadt, 2001) and meta-analytic reviews have shown intentions to be the best predictors of actual behaviour (Armitage & Conner, 2001).

A small number of ISL investigations have been carried out concerning environmental based exhibitions (e.g. Sutter, 2008) and health related initiatives with a behavioural focus. Cartmill and Day (1997) found a visit to a museum exhibition on illicit drugs, including an exhibition, film and, notably, a presentation or show, significantly reduced intention of drug use. Effects persisted two weeks following. Other studies on the travelling exhibition *BodyWorlds* have found similar results, with changes in intention being recorded for various health behaviours, including smoking, healthy eating, exercise and dental care (Carney et al., 2009).

Science shows in particular can be effective tools to influence behavioural intentions, including in difficult areas such as HIV AIDS (Walker et al., 2011) – this research is dealt with in detail later. Similar demonstration-based shows have also been used to communicate HIV AIDS in Germany, however with more focus on the science and less on motivation and behaviour change (Korn-Müller, 2012). Research on this show was not available. Demonstration-based shows aiming for overt motivation are, however, quite rare, with providers usually opting for traditional theatre approaches when tackling social issues. Many performances of this type address environmental issues,

for example sustainability, recycling and climate change (e.g. Our Planet Enterprises, 2008). Health messages are also a common theme, e.g. The Liberty Science Centre in the United States used a laser show *Extreme Choices* and traditional theatre play *Hot Air* to communicate anti-smoking messages to school students (Koster & Baumann, 2005). Evaluation showed the show and theatre piece communicated anti-smoking messages effectively, with students understanding the negative health consequences of smoking and the importance of their choices (ibid.). While it is likely a participant's understanding of the health risks related to their decisions could lead to motivation and behaviour change, these aspects were, however, not reported on.

Amongst ISL providers, zoos and other environmental organisations have been most active in advocating directly for behaviour change. In contrast to science centres, zoos and other live-animal experiences have been overt campaigners for behaviour change for many years, some rating it as their highest priority (Patrick, Matthews, & Ayers, 2007; Woollard, 2001). Significantly for this thesis, a variety of environmental ISL theorists have argued that emotion plays an important role in the ISL experience and that it influences behaviour (Ballantyne & Packer, 2005; Ballantyne et al., 2007; Smith, 2008), although empirical evidence is limited to a few examples. One such is a study on turtle conservation that showed 'emotional arousal' was associated with stating intention and, to a lesser degree, taking action to conserve turtles (Howard, 1999). Emotional arousal was measured with three semantic scales: stimulating-boring, exciting-dull and inspiring-uninspiring. Another study looking at characteristics of an aquarium presentation found that communication strategies using 'emotional connection' had the greatest impact on personal responsibility for conservation

behaviours, even when compared to strategies that emphasised personal responsibility (Mortan & Yalowitz, 2003).

> Emotional connection score had a greater influence on visitor response to personal responsibility statements than the frequency of references to personal responsibility during the program. Further research should be conducted to examine which types of emotional connection messages are the most effective. (ibid., p. 8)

Further environmental ISL studies drawing on qualitative data also suggest changes to attitudes and behaviour were associated with arousing emotions (for a review see Ballantyne & Packer, 2005). Other apparently contradictory research in zoos, however, suggests limited empirical support for emotional arousal facilitating changes in attitudes, intentions and behaviour, however still argues for the importance of emotions and calls for more research (Smith, 2008). The general conclusion of this body of literature is that while emotions are important and appear to play a role in influencing motivation and behaviour, there is still much to learn. This is especially true in the context of a science show.

3.4. Findings of the literature review

This review of the literature identifies a host of variables that may be motivational features of a science show. The fact that many of these variables are implicated by different and often disparate literatures – motivation psychology, emotion psychology, formal and informal learning, and science shows – adds strength to these conclusions via triangulation. Another outcome is, however, that different literatures and models use different terms to describe very similar things. This summary will clarify these terminology issues while bringing together findings from different areas.

There are numerous connections and overlaps between the motivational features discussed, as shown in Figure 2. What various models term I-curiosity, intrinsic value, and the emotion components of intrinsic motivation and SI are all essentially the same thing: the motivational experience of interest and enjoyment. Although each of these models places interest and enjoyment in a different context, this holistic view suggests this interest-enjoyment nexus is an important part of understanding motivation in ISL and science show contexts. Moreover, evidence points to a family of motivational features termed immediacy (including enthusiasm, humour and interactivity) primarily acting on this interest-enjoyment nexus.

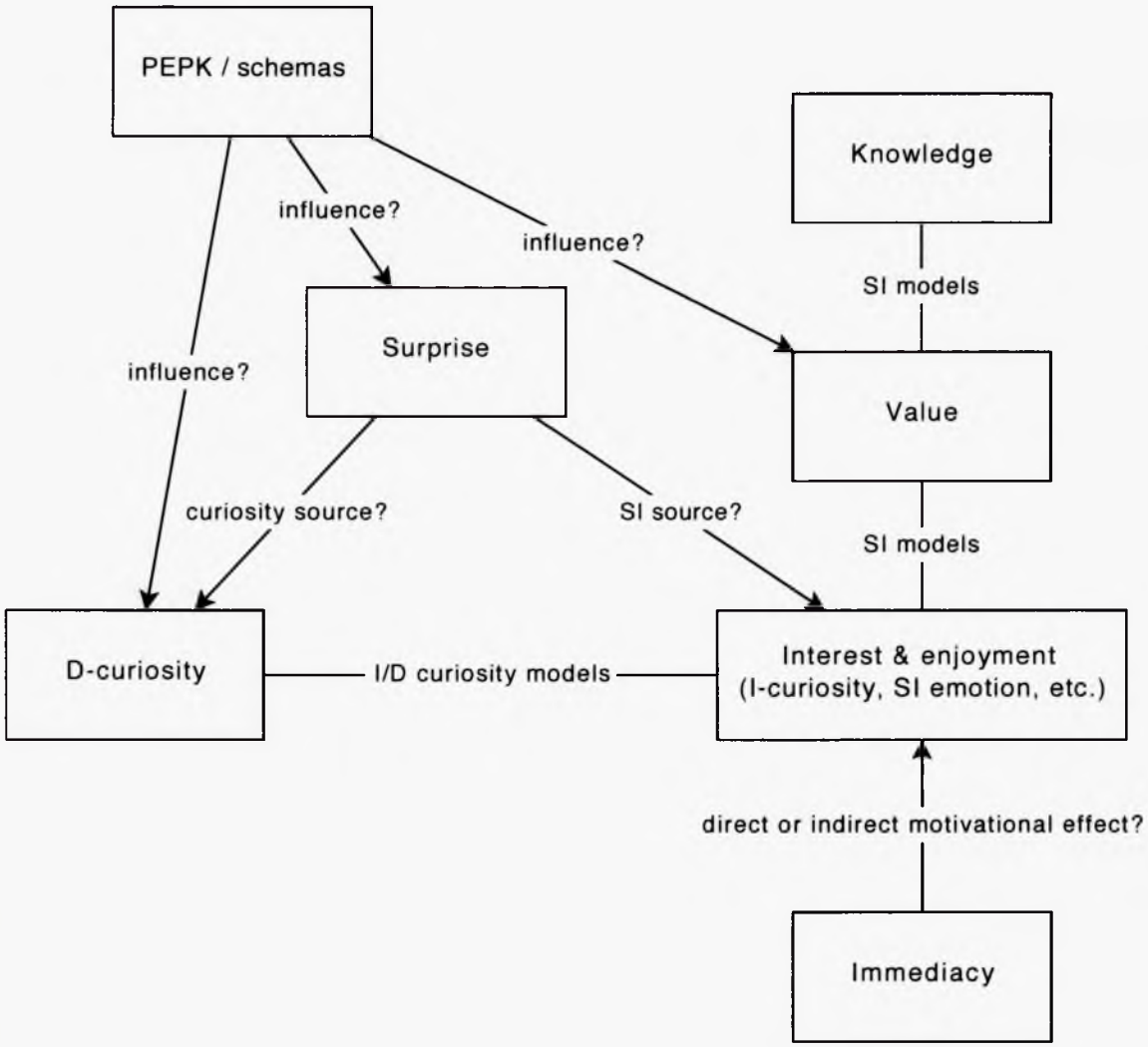

Figure 2. Relationships of the motivational features indicating models and sub-questions.

Across all the models discussed, SI appears most useful for ISL experiences as it places this interest-enjoyment nexus ('emotion' or 'SI-feeling') along with value – another key motivational variable, especially in informal settings. Evidence points to value being involved in sustained SI, such as over the duration of a show, and also in motivating thoughts and actions following the show. The third component of SI is knowledge, although cognitive learning is not a central focus of this thesis.

I/D-curiosity models allow the differentiation of I-curiosity (interest and enjoyment related to information-seeking) from a second form of curiosity, D-curiosity (tension and intrigue associated with searching for missing information). D-curiosity appears to be important in the context of a science show as it is arguably what audiences are experiencing during counterintuitive discrepant event demonstrations, which the small literature on science shows suggests are particularly engaging and memorable. This is supported by evidence that D-curiosity is a stronger form of motivation when seeking understanding.

Curiosity, in particular D-curiosity, also draws attention to the role of surprise, as both hinge on a lack of knowledge (schemas) to make sense of a surprising, curious event. In theory, schemas, or prior experience and prior knowledge (PEPK), influence surprise and curiosity, as well as value – however there is limited empirical data in these areas. Similarly, the exact role of surprise is unclear as researchers cite it as a forerunner to both curiosity and SI depending on the model they are working in.

The literature suggests all of these emotions (interest, enjoyment and surprise) and motivational variables (value, curiosity and immediacy/enthusiasm) appear to have the potential to influence motivation from a science show. They are the potential motivational features these chapters aimed to identify.

3.4.1. Refinement of research question and questions emerging from the literature

I began this chapter by breaking down the main research question – What features of a science show motivate people? – into two parts, (1) do shows motivate people, and (2) what are the motivational features of a science show? Having identified potential motivational features, these questions can be revised to:

1) Do shows motivate people?

2) Are the identified motivational features associated with motivation?

Along with these questions flowing from the central research question, this review raises additional sub-questions that address gaps in the literature:

1) Is the I/D-curiosity distinction valid during a learning experience like a science show?

2) Is surprise linked to D-curiosity, SI or both?

3) Are the theorised links between PEPK and surprise, PEPK and curiosity and PEPK and value reflected empirically?

4) Is immediacy a motivational variable in its own right, or are its effects mediated via another motivational variable or emotion(s) as suggested in the literature?

These sub-questions essentially ask about the relationships between the identified emotions and motivational variables, as indicated with connectors in Figure 2. While uncovering the features of a science show that are directly related to motivation is the focus of this thesis, understanding indirect effects on motivation, and other interactions between motivational features is also important.

Chapter 4. Methods

4.1. Overview and introduction

Having identified potential motivational features over the past two chapters, this chapter discusses the methods employed to determine their relationship to motivational outcomes. Initially, arguments for two overarching features of the method are presented: the largely quantitative survey-based method, and investigating different shows with different instruments. I then categorise the kind of motivational outcomes inherent in the different shows, and describe the shows themselves. Following that, an overview of the processes and considerations in designing the survey instruments is given. The data collection, processing and statistical analyses are then described. Finally, limitations of the method are considered.

4.2. Research methodology

4.2.1. Rationale for data collection methods

As discussed, very little in-depth research on science shows has been conducted. The majority of examples of science show research are summative evaluations, typically concerned with measuring a broad range of outcomes in limited depth, with a focus on descriptive reporting of outcomes rather than mechanisms that lead to them. While useful, studies of this nature have limited potential to inform development of science shows. The exceptions amongst the science show literature, as discussed earlier, are McCrory's (2010) qualitative PhD research into emotional engagement techniques used in science shows, and Sadler's (2004) Masters dissertation on recall of science

show content based of different demonstration types, although using a very small sample. A major limitation of all this research is a lack of quantified conclusions about what is important in a show; that is, we know roughly what matters, but conclusions about how much it matters are typically based on minimal data.

This research is chiefly concerned with the motivational features of a science show, especially their relative strengths, hence a primarily quantitative survey-based approach was taken. This approach built on and addressed limitations of the science show research mentioned above; it allowed in-depth, quantifiable, comparable, mechanistic investigation of motivational features and outcomes across a large diverse sample. Moreover, it produced quantitative evidence to build on previous qualitative findings.

Surveys were used to address research questions posed in this thesis as they are an optimal tool for studying a large diverse population and measuring variables such as attitudes and behaviour (Corbetta, 2003). They are a useful tool for explanatory studies looking at relationships between multiple factors simultaneously, as outlined by Singleton and Straits (2005):

> Surveys are used extensively for both scientific and non-scientific purposes, largely because of their ability to describe large populations in terms of a broad range of characteristics, attitudes, and behaviour. Relative to other strategies, surveys generally are more flexible in that they can be used with equal facility for both descriptive and explanatory research and can address a wider range of research topics. (p. 259)

In addition, quantitative methods have the advantage of showing the relative importance of different variables across a broad sample. Both the literature review

and my experience performing shows suggest that many of the variables under investigation are likely to have effects on motivational outcomes: what is less certain is to what degree. Quantitative methods are therefore most robust for investigating relative strengths and gathering concrete answers on the relationship between motivational features and outcomes.

Practicality of data collection is also a consideration. This research has been deliberately conducted in authentic settings, that is, 'real' science shows being done as they would for any audience. Conducting research in such settings, as opposed to inviting people to watch a show exclusively for research (an experimental setting), helps improve ecological validity, minimises bias and makes conclusions more generalisable. It also means, however, that data collection needs to be quick and suitable to fit around the show and audience's schedule, making surveys an appropriate option.

4.2.2. Replication with different samples, shows and variables

Replicating studies is a primary way of increasing confidence in findings, hence this was an approach followed in this work. In the social sciences, one way to ensure findings will rigorously answer a research question – as opposed to being an artifact of a specific method and set of circumstances – is to use replications involving slightly different stimuli, or survey instruments, or times, places, contexts and samples (Singleton & Straits, 2005). The range of shows investigated, as described in the next section, allowed many of these factors to be varied between studies. Over the course of the data collection period, factors were varied both systematically and for reasons beyond the researcher's control.

Systematic method variations were largely due to the ongoing nature of the research, where each study informed the next and different shows were more appropriate for investigating different variables. For example, survey items that proved reliable in early studies were used again, while unreliable items were revised or discarded. In addition, when several studies had adequately addressed a particular question, e.g. the effects of a specific variable, then the focus on measurement was shifted elsewhere. This ongoing 'tweaking' resulted in progressive replications of the method between studies, as well as honing research instruments and allowing investigation of a wider range of variables. This is discussed in detail below. Another systematic replication was embedded in the selection of shows. In replications across different shows, measurement concentrated on variables and outcomes appropriate to that show. Moreover, shows were selected to ensure a range of topics, aims, audience types (primarily school versus public) and presenter styles. This is discussed in more detail in section 4.3..

While mainly done systematically, replication across different samples, times, locations and attendance contexts was in part opportunistic. I seized on opportunities to collect data from many different shows, which led to different samples and demographics (i.e. age distribution, school versus public, family groups versus individual adults), times (i.e. weekdays/weekend, time of day and show duration) and locations (i.e. university facilities, science centres, general public events, in Australia and South Africa).

While not a focus of this research, replications across attendance contexts are an important consideration. Research in museums has shown that visit motivations and the associated identity that visitors adopt are important for understanding learning and how visitors judge satisfaction and benefit (Falk, 2006). In addition to the basic

identity a visitor may have (e.g. parent, child, student, etc.), Falk found visitors could be meaningfully divided into five categories aligned with their motivations to visit. While his research did not investigate motivational outcomes of these different identity groups, Falk (ibid.) concludes:

> Preliminary findings suggest that these identity-specific motivational categories might help to explain the long-term learning impacts of a museum visit. (p. 151)

Given the broad view of 'learning' used by Falk (essentially any cognitive or affective impacts), it is reasonable to assume that identity-specific motivational categories will influence motivational outcomes. This research did not seek to assess the identities assumed by visitors, but did draw data from various attendance contexts which were likely to provide diversity in identities and visit motivations. These included: youth in arranged school-excursions and free-choice family visits; shows in science related (e.g. a science festival) and non-science related contexts (e.g. Fathers Day); and, shows marketed and presented as having different benefits (i.e. being 'fun' versus educational), which may influence identities adopted (Falk, 2006).

Replication of studies with the slightly different features described above provides greater confidence in findings. It means, when taken together, that the findings are not specific to any one show, audience, setting, method, or other variable discussed above. Hence, the systematic, opportunistic and incidental variations resulted in conclusions with greater generalisability and reliability, along with increased opportunity to discover nuances within the data.

4.3. Shows investigated

4.3.1. Different shows, aims, outcomes and measurement

The central theme of this research is the investigation of motivational features and their outcomes in science shows. These depend to a large degree on the shows themselves, hence this research investigated several different shows (as described in section 4.3.5.). While all the shows investigated contained elements that should provoke the identified motivational features – outcomes to which most science shows aspire regardless of whether the presenter consciously aims for them – only a subset had overt motivational aims. When assessing the motivational outcomes on audiences, it is important to consider the *intended* outcomes of the show. This also extends to the measures used to determine such outcomes; that is, items and scales should fit with the aims and hence likely outcomes of the show. The variation in measurement of motivational outcomes based on show aims is an important point to bear in mind when comparing the different studies in this thesis.

Given these differences (the show itself, intended motivational outcomes, and their measurement), it is important to divide the science shows studied here into two categories: those with subtle and those with overt motivational outcomes. These categories are used throughout this thesis. I will discuss their nature below and briefly note the implications for measurement (see later sections for details). As no literature exists in this area, this distinction is drawn on my professional observations, having watched, performed or read about a wide variety of science shows over the past decade.

4.3.2. Shows with subtle motivational outcomes

Most professional science shows contain some motivational aims, however mild. These may include things like trying to foster positive attitudes towards science, showing that science is fun, generally mentioning science careers or future science study, or presenting science in an inspirational light. These aspects are described as *subtle* motivational outcomes. Half the shows investigated in this thesis aimed for subtle motivational outcomes. Elements of a show that convey subtle motivation are usually incidental, minor parts (e.g. as part of a wrap-up or linked to a demonstration) that are communicated indirectly rather than blatantly stated. This is not to downplay the importance of such messages, nor the potential outcomes from them, but to acknowledge that this sort of show's primary aim is not to motivate audiences towards specific actions, but to entertain, educate and promote a positive view of science. This needs to be taken into account when looking at outcomes. Nevertheless, these shows may have effects on more general motivational dispositions towards science.

Scales used to measure motivational outcomes in shows of this type reflected these subtle aims; typically they contained less concrete, more general attitudinal measures, such as asking people if they were more inspired or positive towards science.

4.3.3. Shows with overt motivational outcomes

Shows that primarily aim to motivate people are rare amongst demonstration-based science shows. While slightly more common in science theatre, plays or presentations (e.g. on illegal drugs and smoking (Cartmill & Day, 1997; Koster & Baumann, 2005) or interactive science workshops (Corfield, 2011), I am unaware of demonstration-based shows with such specific motivational aims external to those studied here – though it is likely they exist. These overtly motivational shows expressly set out to use science

shows to motivate audiences toward specific goals and actions, such as encouraging behaviours like recycling or condom use. Two shows investigated in this work – on the subjects of climate change and HIV AIDS – expressly aimed for motivational and behavioural outcomes. While both incorporated demonstrations, only the show on climate change could be considered a fully-fledged demonstration-based show.

Scales used to measure outcomes from shows like these are designed specifically around the show content and aims; they are highly concrete, asking about specific behavioural intentions (the best predictor of actual behaviour: Ajzen, 1991).

4.3.4. Ensuring balance of researcher-presented and externally-presented shows

Effects due to the researcher are largely unavoidable in social research, especially in settings where the researcher is actively part of the study stimulus. For this reason, a mix of researcher-presented/written and externally-presented/written shows was studied. Shows I presented and wrote consciously used content and presentation techniques to influence the features under investigation (e.g. making content more surprising, or highlighting value). Moreover, instruments were designed with detailed knowledge of the show content and presentation style, meaning I influenced both the show and its measurement. In itself, this can be advantageous as the show was more likely to stimulate the responses under study, flesh out relationships, and better measure them. As audiences were occasionally aware that the presenter was also the researcher, this may have influenced their responses.

If the sole source of data were researcher-presented/written shows this could be problematic, as the interaction of show stimulus and measurement may restrict the generalisability of conclusions to other shows. Hence externally presented shows were

also studied. In particular, data presented on the show *Burning Issues* by Dr Peter Wothers involved large samples gathered at a show with which I had no connection. That is, the presenter was unknown to me until data collection, I was unaware of specific show content, and only vaguely aware of presentation style. This minimised biases in instrument creation, and I had no influence over the content or presentation style. Moreover, it minimised biases in analysis that may have been present when investigating shows I presented. Similarly, I did not present the show on HIV AIDS, however I did co-write the show and provided ongoing feedback on content and presentation.

4.3.5. Description of shows investigated

- Subtle motivational shows: *Going Ballistics* and *Booming for Beginners*

These two shows followed the same general style and involved a combination of physics and chemistry content. Various demonstrations were featured, including discrepant events (as discussed in section 3.1.) that were specifically designed to enhance surprise, counterintuition and curiosity. Demonstrations typically used everyday items and frequent efforts were made to show the relevance to everyday life, that is, to highlight value. I created and presented these shows, hence many of the variables under study (i.e. value, immediacy, and specific emotions) were considered in the content and performance of the show. The motivational outcomes aimed for in these shows are best categorised as subtle. General public audiences (primarily families) attended the shows in a free-choice, free of charge context. The vast majority of shows were run as part of larger science-based events (National Science Week and the Australian Science Festival) at science-related venues.

- Subtle motivational shows: *Burning Issues* (lecture demonstration)

Burning Issues was presented at the Australian National University (ANU) by Dr Peter Wothers, a chemistry lecturer with extensive experience in chemistry education based at the University of Cambridge. The show fitted the general format of a lecture-demonstration and featured numerous chemistry demonstrations, primarily done with laboratory equipment, along with a supporting PowerPoint presentation featuring chemical equations. Content was linked to some degree to everyday contexts, albeit less directly than other shows studied in this work. Dr Wothers presented in an upbeat, engaging manner, however the style of the show was somewhat less theatrical when compared with other shows studied here. Two similar shows were presented, one to secondary school students who attended as part of teacher-organised free-attendance excursions, and the other to the general public, who attended in a free-choice context at no charge. As discussed above, the researcher had no contact with Dr Wothers nor any input into or detailed knowledge of the show, so creation of instruments and selection of variables studied was largely independent and informed by research on other shows.

Burning Issues is best categorised as subtly motivational in that it generally aimed for less concrete outcomes such as presenting chemistry as exciting, interesting, accessible and fun. The outcomes were more intended to occur by 'osmosis' than via a blatant advertisement for chemistry. Indeed, subsequent discussions with ANU Chemistry staff found that one of their aims was to positively influence peoples' perceptions of chemistry. Slightly more emphasis was placed on encouraging chemistry studies during school performances, such as reference to what was learnt in class or mentioning chemistry careers briefly. Although such messages did not form a

major part of the school shows, they were introduced by ANU academic staff that mentioned the university and also held in a chemistry lecture theatre. These aspects may influence overt motivational outcomes such as intention to study at university.

- Overtly motivational shows: *Sustain-Ability! The climate change show*

The main focus of this show was on ways people can help address climate change, both in their everyday lives (e.g. choice of fuels, using renewable energy, etc.) and to a lesser extent through science and technology (e.g. carbon capture and storage, hydrogen fuel, etc.). It also included a short introductory section on what climate change is, the greenhouse effect, the gases involved and their sources, and two of the potential impacts of climate change. Demonstrations were used throughout to convey information and model/reinforce target behaviours.

I presented and wrote the show and considered how the motivational features under study might be incorporated into content and presentation, as well as integrated ideas from the literature on environmental behaviour. For example, efforts were made to try and motivate behaviours that were accessible to the audience, such as recycling over which they had 'perceived behaviour control' (Bamberg & Moser, 2007); to present a positive as opposed to fear-based message (O'Neill & Nicholson-Cole, 2009); to provide a science-based rationale for why behaviours helped; and, subtly, to incorporate some drivers of environmental behaviour such as social norms (Bamberg & Moser, 2007). Care was taken not to 'preach', be manipulative or present an unbalanced view. The approach to fostering motivational and behavioural outcomes, while obvious, was more 'encouraging' than 'directing'.

- Overtly motivational shows: *The Alarming AIDS Adventure*

These shows were presented at the University of Zululand Science Centre in Richards Bay, South Africa. Additional background regarding the science centre, HIV AIDS and related behaviours is provided in the next section. I co-wrote but did not perform the show, however I provided ongoing feedback on content and performance. Two people presented the show, one playing the role of a curious student, the other a 'scientist' character. Shows were presented by local science centre staff either in English or isiZulu language, depending on the audience. Prior to this research, the show was evaluated to ensure it was well received by students. Feedback was gathered from local HIV AIDS workers/scientists and Zulu science centre staff to ensure the show was scientifically accurate and culturally appropriate.

The show contained a mix of serious messages and light-hearted moments to engage students, with motivation of safe HIV AIDS behaviour the dominant theme throughout the show. Multimedia, props, analogies, narrative and demonstrations were used to explore the topic, using the HIV acronym in reverse as a structure. The first section discussed viruses, while the second covered the immune system with reference to HIV. The third section explored the human aspect and behaviour, presented by 'scanning' two hypothetical people and discussing safe, unsafe and misconceived behaviours. The two presenters and audience were then 'shrunk' and travelled in a submarine-like ship into the hypothetical person whose 'scans' revealed unsafe behaviour. Animations were used to show the shrinking process, the lifecycle, genetics and cell biology of HIV, and action of antiretroviral drugs. Demonstrations using models showed the role of RNA and other aspects of the virus. The show then promoted destigmatising HIV,

discussed other social issues, encouraged testing, and reiterated there is no cure for HIV AIDS.

The show concluded with a large demonstration where mixing fluids in glasses was used as an analogue for mixing fluids during sex: the method of HIV infection. 20 volunteers each had a glass of water, one of which had sodium hydroxide (a strong base) added to it to represent being HIV-positive. Depending on a behavioural instruction on each glass (i.e. abstain from sex – do not share fluids with anyone), volunteers either exchanged fluids with everyone, a single partner, or nobody. The fact that the fluid mixing is analogous to the exchange of bodily fluids that transmits HIV was stressed. At the end, acid-base indicator was used as an 'HIV test' to show how the virus had spread depending on behaviour, emphasising the show's primary message.

4.3.6. Background: HIV sample and study

The following section provides background on HIV AIDS in South Africa and the region where the study was conducted. The country is facing an HIV epidemic, with a mean HIV prevalence of 18%, or approximately 5.6 million people as of 2009 (UNAIDS, 2010). Approximately 850 people die of the disease each day (ibid.). Most new infections occur in adolescents and young adults, with approximately one third occurring in 15-24 year olds (Rehle et al., 2007; UNAIDS, 2008). In the area close to the science centre were research was conducted, prevalence rises from 11% of females and 2% of males in 15-19 year olds, to 40% of females and 30% of males in 20-29 year olds (Welz et al., 2007). Welz and colleagues described the area as containing "some of the highest population-based infection rates yet documented worldwide" (ibid., p. 1471), with 27% of females and 13% of males HIV-positive. A central mission of the research in this

thesis is to establish what role science centres and shows may be able to play in helping address this problem.

To design the show and survey instruments, motivation and behavioural intention across a range of behaviours needed to be considered. Motivation to engage in HIV-related behaviours (i.e. behavioural intentions), such as condom use, is a good example of overt motivation. Unsafe sexual behaviour is the main cause of HIV infections in South African youth (Eaton, Flisher, & Aarb, 2003; Simbayi, Chauveau, & Shisana, 2004), hence promotion of sexual abstinence, condom use and single-partner relationships are common in youth interventions. Broader behaviours associated with HIV are also important when considering the social context surrounding HIV. They include discussing HIV with friends or family, being tested for HIV, being aware of one's HIV status and reducing behaviours that stigmatise HIV. All these aspects were included in the show and scales to measure motivation (which are discussed generally in section 4.5.).

Literature suggests demographic differences play a significant role in HIV AIDS in South Africa, with gender, residential location (rural/urban) and age being significant variables. Compared to males, females have higher HIV prevalence, are infected earlier, have lower rates of multiple sexual partnering and poorer HIV knowledge; to a lesser extent they are less sexually active, older at sexual debut (abstinence) and use condoms more, although conflicting data exists on these latter three differences (Akande, 2001; Eaton et al., 2003; Peltzer & Promtussan, 2005; Shisana et al., 2008; Simbayi et al., 2004; Welz et al., 2007). While there are fewer data on rural/urban differences, compared with their urban counterparts, rural students have higher rates of multiple sexual partnering, earlier age of sexual debut, much lower HIV knowledge,

greater sexual activity, and engage in fewer HIV preventative behaviours (Eaton et al., 2003; A. Harrison, Cleland, Gouws, & Frohlich, 2005; Kaaya et al., 2002; Kelly, 2000; Peltzer & Promtussan, 2005). As one would expect, sexual behaviour and HIV prevalence increase with age, however less is known about associated behaviour except that multiple partnering increases with age (Kaaya et al., 2002).

4.4. Samples

Following ethical approval for the research (ANU HREC protocols 2009/616, 2009/330; see Appendix C), data were collected in a range of venues where science shows were performed. The venues were typically theatres or lecture halls where the general public attended free shows as a free-choice activity. Free-choice is an important aspect as it means data presented in this thesis were largely from participants who were motivated to attend and hence would probably view shows more favourably. In addition, these participants were likely to have a generally positive attitude toward science, or learning experiences, or both, and may not be representative of the public at large.

In two studies, school groups attended a free show but the excursion was organised by teachers and show providers, meaning students did not instigate the activity. These groups are hence more representative of a non free-choice general student audience. In some cases, however, students had opted to study science in later years and hence may be subject to a similar pro-science bias as described above.

4.5. Survey design

4.5.1. Overview of survey design process

The scant research on science shows, in particular quantitative research, means there are no established survey instruments, scales or items to measure audience response. With the exception of the Differential Emotions Scale (DES; Izard, 1977), items and scales for all studies presented were created 'from scratch', but were often loosely influenced by questions from formal education research. Due to the practicalities of researching with authentic audiences and shows, and the limited timeframe, extensive piloting and pretesting of each survey instrument was not possible. Instead, instrument and item development occurred via refinement over multiple iterations – an evolutionary fashion – as studies progressed.

Full item wordings and copies of the survey instruments and can be found in Appendices A and B, respectively.

4.5.2. Survey instrument characteristics

Based on the rationale presented in section 4.2.1., surveys were the primary method of data collection. These mainly comprised 5-point Likert-scale items: these scales were used as they are simple and familiar to audiences and also give an indication of the strength or intensity of response (Singleton & Straits, 2005). This is particularly important when measuring behavioural intentions as it provides an idea of the conviction of intention (Fishbein et al., 2001). Differing views on the number of scale points exist, with several authors arguing that increasing the number of points increases reliability, validity and precision and recommending use of scales with seven or greater points (Alwin, 1997; Cummins & Gullone, 2000). On the other hand,

increasing the number of points increases complexity and time for survey respondents (Singleton & Straits, 2005), which may be exacerbated with audiences such as young children who are less familiar with scale-response questions. Five-point scales using strongly disagree to strongly agree labels are widely used, hence should be familiar and easy to use for general audiences. Survey space was also an overriding practical issue after instances of non-completion and anecdotal feedback suggesting the first study's four-page survey was too long. Following this experience, it was decided that surveys should be no longer than one double-sided A4 page (two pages).

Surveys also included qualitative open-ended short-answer questions and comments that provided additional context to the quantitative data. These data, however, do not form a major component of the final data presented in this thesis. Open-ended questions were designed to complement the closed questions as they have potential to reveal logic of responses, provide scope for unexpected responses, and deepen the researcher's clarity and overall understanding (Singleton & Straits, 2005). Open-ended questions were, however, kept to a minimum because of space issues and in consideration of the low quality, brief responses often characteristic of self-administered, written surveys (ibid.). The argument presented in this thesis is therefore structured around quantitative results – the main focus – with qualitative comments occasionally providing additional context and examples.

Surveys were formatted in Microsoft Word, with consideration of both practical and aesthetic issues. The layout presented items in batteries to save space and grouped sets of questions for ease of comprehension (e.g. grouping general response to the show separately from motivational outcomes). Surveys utilised a table format so response categories appeared only once (Corbetta, 2003), while also being compatible

with the *Remark* automated data capture software (see section 4.7.1.). Open-ended questions were positioned to avoid too many consecutive closed-ended questions, to group related closed- and open-ended questions, and not first or last (where possible). These tactics have been found to improve the quality of responses (Corbetta, 2003; Singleton & Straits, 2005).

4.5.3. Development of items

In early studies, a large pool of potential items was created based on the literature review, my experience in science shows and audience responses, and the particular variables under investigation. Common guidelines for wording social research questions were followed (e.g. Corbetta, 2003; Singleton & Straits, 2005). Issues of simplicity, question length, ease of reading, straightforward syntax and appropriate vocabulary were particular considerations, given that very young respondents were amongst the intended sample.

These items were then reviewed by three or more colleagues, wording was revised and items judged as weak or flawed were dropped. Refined items were then formatted into a draft survey and completed by different colleagues, who were both timed and asked for feedback considering the target audience. This often resulted in further fine-tuning of items and layout. Following data collection, factor analysis and scale reliabilities were used to inform scale development (discussed in detail in section 4.7.2.). These statistical methods often revealed previously unnoticed issues with wording or interpretation, or resulted in unexpected and serendipitous results. Items shown to be reliable were used in subsequent studies, while weaker ones were replaced. In this way, the items and scales used for measurement evolved over a

number of iterations. Development of these science show-specific scales is an additional outcome of the research.

4.5.4. Critical issues considered in item design

Two interrelated issues were considered in the evolution of items: creating 'concrete' items, in particular for items measuring behavioural intentions; and mitigating ceiling effects on measurement through item wording. The concreteness of an item refers to how specific it is. In the case of a behavioural intention, specificity can be improved by trying to incorporate where, when and how the behaviour may be enacted – referred to as an 'implementation intention' (Gollwitzer & Brandstätter, 1997). Studies have shown that intentions with higher degrees of concreteness predict behaviour more accurately (Ajzen, 1989). Moreover, studies in science centre environments on health issues have argued that measuring high-concreteness intentions is a sufficient measure of success: this was outlined by Cartmill and Day (1997) while researching a program targeting adolescent alcohol and drug use:

> For museum evaluation, it is sufficient to know that a visitor can be asked concrete questions about intended behaviour in order to measure a program's effectiveness in encouraging good health. (p. 151)

It should be noted that concreteness of items improved considerably between the HIV AIDS study, which had to be completed very early in the data collection period, and later research on the *Sustain-Ability* show (climate change).

Ceiling effects are an issue in many types of social research. Unpublished evaluations I conducted prior to this PhD showed that when gathering data from science shows, particularly with audiences containing young people, ceiling effects were evident with

many participants consistently scoring items at 5 on a 5-point scale. Reasons for excluding the use of scales with more than five points have previously been discussed. Three strategies were used to combat ceiling effects: using more concrete items; wording items at an extreme (e.g. 'I had fun for *the entire show*', italics added here); and using scales of multiple items to measure constructs. Notwithstanding these efforts, ceiling effects still remained an issue and are likely to be for future science show research.

4.5.5. Development of novel multi-item scales

A 'scale' is a set of items that when combined give a score for an overarching construct (not to be confused with the 5-point rating scales discussed above). Such a scale is defined as 'a coherent set of items that are regarded as indicators of a more general concept' (Corbetta, 2003. p. 165). This kind of scale is widely employed to increase the validity and reliability of measurement, particularly of latent variables that describe a broad overall construct that is difficult to observe directly (ibid.), such as immediacy or motivational outcomes.

Apart from the Differential Emotions Scale (Izard, 1977), no pre-existing scales were available to measure experiences and outcomes from a science show, hence novel scales were developed. Another challenge to adapting pre-existing scales was the desire to simultaneously measure several interrelated but distinct constructs, such as interest and curiosity. Much psychological research investigates only one construct at a time, meaning that overlap with related constructs is not often considered. For example, in one study a five-item scale used to measure interest included two items referring to curiosity (Reeve, 1989), which while acceptable given the aims of the study in question, would not be appropriate in the current research. The overriding

consideration, however, for developing scales 'from scratch' was the lack of rigorous quantitative research on anything similar to a science show.

The development of scales followed general procedures set out by Corbetta (2003), but also drew on literature and item wordings more closely related to the research topic including development of scales for enjoyment of web experiences (Lin, Gregor, & Ewing, 2008) and situational interest in academic domains (Linnenbrink-Garcia et al., 2010). Corbetta describes four phases in general scale development: (1) item conception and writing based on the literature, (2) item administration, (3) item analysis (reliabilities, etc.), and (4) scale validation and unidimensionality checks. Due to limitations around data collection, data from early studies presented here were used both in an exploratory fashion to develop scales and for subsequent analysis; in an ideal world these two steps would be performed on different samples following the procedure used by Linnenbrink-Garcia and colleagues. More information on statistical procedures employed in scale development (phases 3 and 4 above) and calculation of scale scores are described in section 4.7.2..

Scales were developed for the identified motivational features – curiosity, value immediacy and the emotions of surprise, interest and enjoyment – and motivational outcomes (the nature of which varied with the show under study). Data from these scales feature in most of the studies presented. Scales for some constructs less central to the research were also developed, such as knowledge, but these only feature in selected studies. Items for value and immediacy scales were based on discussion of these constructs in the literature (as per Corbetta's phase 1) and a wide conceptualisation was taken to ensure content validity. For example, the value scale shown in Table 1 combined items assessing personal relevance, utility and links to

everyday life. Once reliable scales were established, items in these scales remained similar from study to study, however single items were occasionally substituted depending on the show and to develop better items for the scale, or shorter versions of the scale (fewer items) were used.

I could see how the show related to things in the outside world
The show was relevant to my life
The information in the show was important to me
There were things in the show I have a personal interest in
The show helped me understand things in everyday life
The show had ideas that I can use myself

Table 1: 6-item value scale used in *Burning Issues* public shows

In contrast, scales for motivational outcomes were much more varied to suit the particular aims of the show (see section 4.3.1.). For shows with subtle motivational outcomes, items typically focused on more general attitudes and actions in response to the show and toward science generally. For example, in shows with overt motivational outcomes, items were more tailored directly to the show aims and focused on behavioural intentions. Therefore, when interpreting results presented in this thesis concerning factors influencing motivational outcomes, it is important to note that the way these outcomes were conceptualised and measured varied from study to study. This will be discussed further in the Results chapter.

4.5.6. Scales for the emotions and curiosity

Two approaches to the measurement of emotions (surprise, interest and enjoyment) and curiosity were undertaken in this research: measurement via appraisals or similar

underlying components and measurement via the Differential Emotions Scale (Izard, 1977). The primary difference between these approaches is that the former relies on measuring the emotion or curiosity through its underlying components or precursors, whereas the latter largely relies on measurement through synonyms based on facial expressions associated with the emotion.

Measurement through appraisals was the method used in the majority of studies presented here. This gave an overall measure that included underlying components, which may highlight important components and flesh out relationships, as queried in the sub-questions. Appraisal approaches did, however, present more challenges. Much of the literature about appraisals investigates their association to particular emotions through retrospective reports of remembered emotional experiences or hypothetical scenarios (e.g. Ellsworth & Smith, 1988). In contrast, my research investigated the immediate emotional response to a science show, which was similar to appraisal research in response to art. Silvia (2005; Experiment 3) used semantic difference scales to measure appraisals, for example this set which measures interest's appraisal of coping potential: Comprehensible–Incomprehensible, Coherent– Incoherent, and Easy to Understand–Hard to Understand. While these items were appropriate for adults, one challenge for this research was writing items suitable for young children or those with limited English proficiency. Early pilot testing during the HIV AIDS study suggested Likert-scales were far better interpreted than semantic difference scales, hence the former approach was used.

Multi-item scales for each of the emotions and for curiosity were primarily based on appraisal approaches (see section 2.4.4) and included an item(s) featuring the emotion term (i.e. 'interesting') along with items tapping its respective underlying appraisals or

components. That is, items in the scale measured the emotion itself (i.e. interest: 'The show was interesting') and its underlying appraisals (i.e. interest's appraisal of coping potential: 'The information in the show was about the right level for me'). An example of an emotion/appraisal scale for surprise is shown in Table 2. In the surprise scale, the first two items measure surprise's underlying appraisals (schema-discrepancy and unexpectedness), while the third item measures the emotion itself. Some emotion scales for interest and enjoyment used in later studies did not employ the appraisal approach. Both factor analysis and Cronbach's alpha were used to ensure reliable, unidimensional scales, as described in detail in section 4.7.2..

Sometimes experiments turned out differently to what I thought
Some results were really unexpected
I was surprised by the show

Table 2: 3-item surprise scale used in *Burning Issues* public shows.

The approach of creating emotion/appraisal scales is robust as it relied on functional precursors to the emotion and on the emotion itself to build an overall scale. A lack of pre-existing items suitable for youth, and a lack of short scales appropriate for the comparatively brief survey format, however, meant new items needed to be created with varying degrees of success. Nevertheless, an appraisal approach more deeply addressed the research questions, so despite these challenges it was the dominant methodology.

Towards the end of the data collection period a second method of measuring emotions, Izard's (1977) Differential Emotions Scale (DES), was trialled. This was partly due to the challenges faced with appraisal approaches and partly to verify that the DES

was useful in the context of ISL research. The DES essentially relies on synonyms to measure an emotion. For example, the three-item scale that measures surprise includes surprised, amazed and astonished. While at face value this synonym approach may seem weaker than an appraisal approach, the items were developed by looking at verbal labels of facial expressions, which are one of the most robust ways to differentiate emotions across ethnicity, languages and cultures. Izard argues that this approach generates 'a set of words for each of the emotions that could be viewed as transcultural definitions' (Izard, 1982. p. 252).

The DES-II is a variation of the scale that measures emotions over a specified time like a show using a five-point scale that assesses frequency of emotional experience (Rarely or never, Hardly ever, Sometimes, Often, Very often). The DES-II was selected for several reasons: it has a long track record of reliability and established construct validity in numerous studies (see Izard, 1977, 1982); it was the only scale including and differentiating the emotions being investigated here (surprise, interest and enjoyment – in total the DES measures 10 emotions); and it was relatively brief, with three items measuring each emotion. One change was made to the scale items to be more appropriate to modern everyday language, changing 'joyful' to 'enjoyable'. Although considered, the DES-III (Izard, 1982), which is a variation of the scale especially for children and adolescents, was not used as items were too long and judged inappropriate given restrictions on survey space and time to complete, and the fact that adults would also be completing the survey. Curiosity is not an emotion so is not included in the DES, hence a new three-item scale based on synonyms was created (wondering, inquisitive and curious) and added to the DES-II items.

4.5.7. Motivational outcomes: post-only measures and pre/post measures

This research is ultimately concerned with the effect a science show can have on motivational outcomes, hence both the final outcome and the amount of change an individual has experienced are relevant. Due to logistical and timing issues in administering surveys, in five studies motivational outcomes were only measured once, following the show, with items worded in such as way to focus on change (e.g. 'Compared to before the show...') – termed *post-only* studies. This approach relies on the participant being able to retrospectively and accurately judge their starting point, which is problematic. In the other three studies, however, both pre- and post-measurements of motivational outcomes were taken, allowing calculation of motivational change (in one study the same approach was taken to measure knowledge change). These *pre-post* studies provided much more stringent evidence for the drivers of motivational change, while also introducing prior motivation as a variable which may predict motivational change. Ideally all studies would have employed pre-post designs, however the limitations of real-world contexts in which shows are presented means this was not always practical.

4.6. Data collection

Self-administered surveys were either laid out beneath chairs prior to the show for large venues, distributed as people entered, or in the case of small audiences handed out at the end. Issues such as people completing surveys before the show had ended or the surveys being a distraction during shows meant that distribution before the show had limitations, however experience showed it resulted in more completions than when they were handed out at the end – something impractical in large audiences in any case. Participants were supplied with a pen.

For pre-post methods, separate surveys on different coloured paper were used and audiences instructed to complete the pre-survey before the show, leaving the post-survey beneath their chair for completion afterwards. Pre-surveys were collected before the show so answers could not be changed retrospectively. Numbered surveys were used to match pre and post while keeping participants anonymous, however matching was crosschecked with gender and age details. During HIV research efforts were made to obscure the repeated measures design, such as placing pre- and post-surveys on clipboards with a blank sheet between to hide the post-survey.

In all shows, completing surveys was optional, although most attendees were willing to participate in the research. Audiences were given a brief verbal background of what the research was about, along with more detailed information sheets posted around the venue (see Appendix C). Basic instructions for completion were discussed such as not writing their name, being honest and noting participation was voluntary but appreciated. Due to the background and level of English language proficiency of participants in the HIV research, more detailed instructions were given in both English and isiZulu language by the show presenters including: how the agree-disagree scales worked including an example; that there were no right and wrong answers – it was not a test; not to copy from peers (which required additional supervision); and that surveys were anonymous so they could be completely honest.

4.7. Data processing and statistical analysis

4.7.1. Processing of surveys and data preparation

Each data set comprised several performances of the same show, or in two cases very similar shows. This approach resulted in larger data sets than looking at individual shows and also smoothed the effects of small variations across shows.

Initially, surveys were coded manually into Microsoft Excel and comments transcribed verbatim. Coding of large data sets became impractical and inefficient, so most data presented in this work was processed with *Remark Office OMR 7* which uses optical mark recognition technology to automate coding of Likert-scale, multiple choice and other 'tick box' type results. Surveys were adapted to use a circle that was coloured in to indicate the response and allowed best mark recognition, however *Remark* also recognises ticks, crosses and other ways participants would indicate answers. After using the software to set up a template for each survey, completed surveys were scanned in and automatically coded. *Remark* allows the researcher to manually review responses in cases where multiple answers were selected on a Likert-item, or the question was left blank, or the participant marked their answer faintly and it could not be recognised, or for some other reason the response could not be automatically coded. Handwritten text was still manually transcribed, however *Remark* simplified this process.

Pre-post data sets from *Remark* were combined in Microsoft Excel using survey numbers, gender and age to match individuals. Non-matching pre- and post-surveys were discarded, however in some cases it was clear how they had been mixed up (e.g. pre- and post-surveys swapped between consecutive numbers) and these were rearranged.

4.7.2. Statistical analysis – main research questions

SPSS Statistics software was used for all subsequent data preparation and quantitative statistical analysis. The approach to analysis was the same for the various studies, however additional steps were required for pre-post designs. These steps included exploring the data structure and informing scale development using factor analysis,

calculating scale scores, calculating change scores (for pre-post designs), and using linear regression to identify relationships – both between motivational features and motivational outcomes (main research question) and between motivational features themselves (research sub-questions). These steps are described in the following paragraphs and shown in Figure 3, which also indicates how the analysis addresses the research questions.

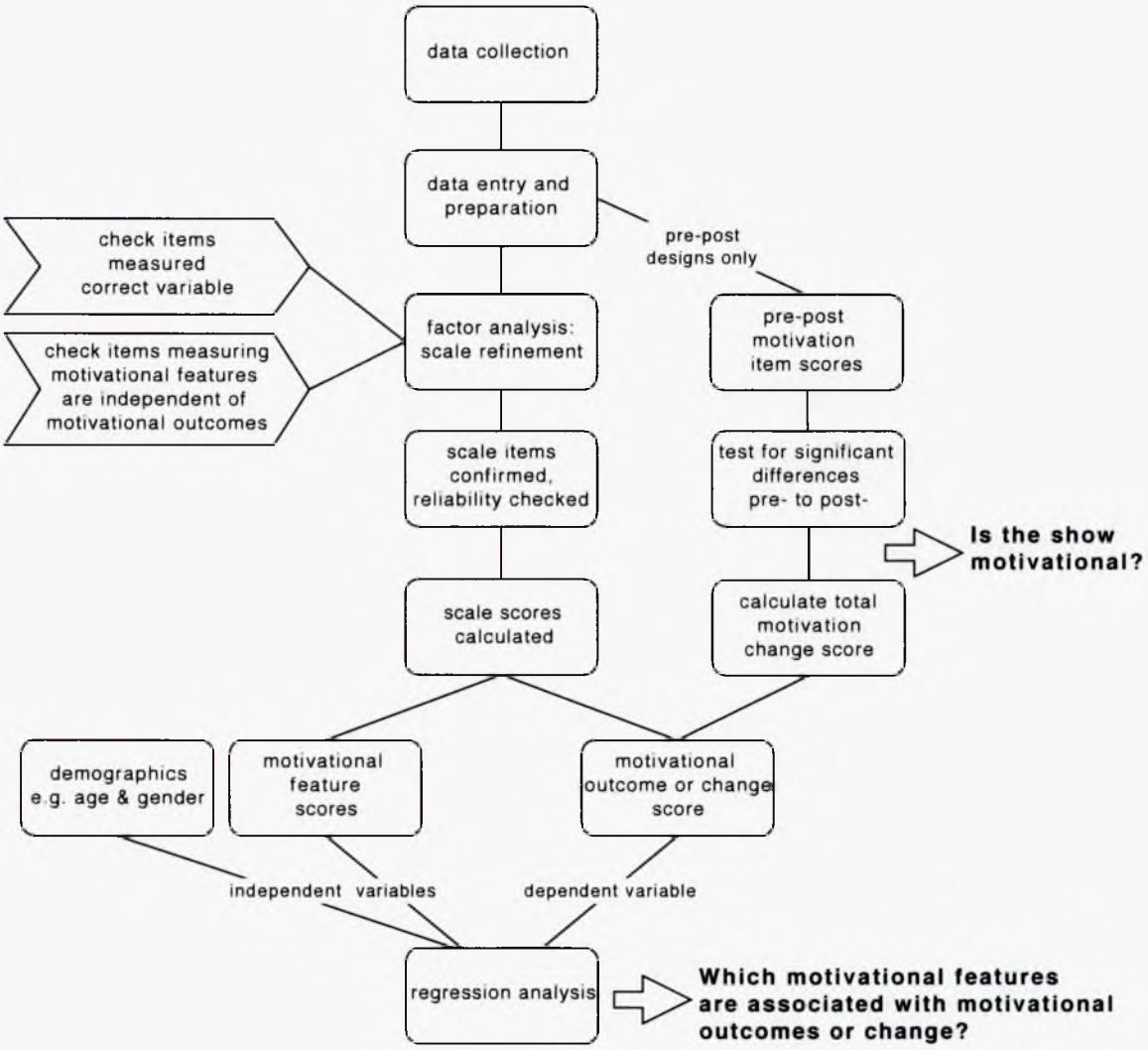

Figure 3. Overview of statistical analysis and links to the research questions.

First, data set structure was investigated using exploratory factor analysis. Factor analysis groups correlated variables into 'factors' and is a useful technique for

exploring the overall structure of a data set. Generally Principal Axis Factoring (PAF) extraction was employed as this technique is recommended for exploring data structure, whereas the more common Principal Components Analysis (PCA) is used for data reduction (Garson, 2009). In addition, PAF is more suited to data sets where underlying latent variables are being measured (O'Rourke, Hatcher, & Stepanski, 2005), as is the case with this research. While PCA can also be used for this, PAF has the advantage of only using the variance that is unique to each variable in the analysis and of all extraction methods, is recommended for non-normally distributed multivariate data such as the sets analysed here (Costello & Osbourne, 2005).

In some cases, the number of factors and factor structure was as expected from theory, however in others the number of extracted factors was fixed based on the number of latent variables involved. Scree plots and Eigenvalues were examined to ensure that the selection of the number of factors was appropriate. Pairwise deletion of missing data was used to maximise the data set size. Factor structure was subsequently investigated to see if underlying appraisals and components would group with their respective emotions or motivational variables (e.g. the grouping of surprise with unexpectedness and schema-discrepancy), and to confirm the validity of grouping multifaceted motivational features (e.g. immediacy). These aspects were ultimately part of the primary reason for factor analysis: to inform scale development.

Using factor analysis in scale development was important as it ensured the scales were reliable measures of the variables. In most cases, the factor structure clearly showed the grouping of items (factors) into the planned scales, however occasionally items intended to be part of the scale did not factor out (form groups) as hypothesised. Reassuringly, unanticipated factor groupings often highlighted problems in item

wording, or suggested serendipitous new leads. An item that did not group with its hypothesised factor (showing a lack of unidimensionality) was typically dropped from a scale. Stray items were, however, included in rare cases where Cronbach's alpha was acceptable, and there were other arguments for retaining the item (e.g. to ensure content validity).

For most scales, however, factor analysis confirmed unidimensionality and discriminant validly of scales. That is, made sure items measured the motivational feature they should (i.e. forming one factor), and were independent of other motivational features and especially motivational outcomes. Items co-loading onto two or more factors show non-independence. Although not the norm, a small amount of co-loading was tolerated between motivational features. This was somewhat expected given the close association of several of the motivational features reported in the literature. Co-loading of an item on a motivational feature and motivational outcomes, however, may have undue influence on regression results. Hence, in this case items were usually dropped from scales – especially where the co-loading had a conceptual basis. For example, when a motivation item measuring information-seeking also loaded onto the curiosity factor it was dropped. In rare cases, where no conceptual basis existed and other reasons existed for retaining the item (e.g. dropping resulted in inadequate Cronbach's alpha), items that co-loaded on both motivational outcomes and a motivational feature were retained. Notes on scale development, co-loading and dropped items are included with the scale items in Appendix A.

Second, scale reliability was tested and scale scores calculated. Typically Cronbach's alpha was greater than 0.7 indicating an acceptable scale reliability, however a small

number of scales used were between 0.6 and 0.7. These were only used where reasons existed for flexibility on the standard 0.7 minimum, such as the scale having only two items which affects Cronbach's alpha, and in cases where the variable concerned was of high importance (e.g. a two-item scale measuring prior knowledge and prior experience). Summated scores were then calculated and then standardised by dividing the summated score by number of items in each scale. This resulted in a score out of five for each variable.

For pre-post designs, additional steps were required to test for significant changes in motivation from pre- to post-. This was done at both scale and individual item levels. Pre- and post-motivation scale scores were calculated to see the overall magnitude of the change (pre-motivation was also used as a predictor in regression analysis). Individual items were grouped into pre- and post- pairs. As most variables were not normally distributed, for individual item tests both t-tests and the non-parametric Wilcoxon Signed Ranks Test were used to identify significant changes from pre- to post- for each participant. Scores also indicated the nature of the change, for example from disagree to agree (2 to 4; a complete inversion of motivation) or from agree to strongly agree (4 to 5; a strengthening of motivation).

Pre-post designs also included steps to calculate a motivation change score. Initially, change scores for each motivation item were calculated, ensuring that any items missing either pre- or post- were discarded and allowing for reverse scored items. These were summed to give a total score for motivation change across all items, in preparation for linear regression modeling. This approach was selected for two reasons: (1) the pre- and post-motivation scales gave high Cronbach's alpha scores suggesting they were measuring a single underlying construct, hence could be

meaningfully combined into a reliable measure of overall change in motivation; and (2) the data did not conform to the extensive statistical assumptions to satisfy a repeated measures linear model, which would allow the regression to be performed with all the pre-items as independent variables and matched post-items as associated dependent variables (however this was attempted).

Third, linear regression was used to identify relationships between demographic variables and the motivational features (independent variables) and motivational outcomes or change (dependent variable). In all but one study, as noted in the results section, sample sizes were large enough to satisfy restrictions of the ratio of cases to independent variables (Tabachnick & Fidell, 1996; while many rules are available, the one used was 104 plus the number of independent variables). Usually all variables were entered into the regression model at once. The exception to this was the HIV study, where demographics and show qualities were entered hierarchically to investigate them separately, as the literature suggested a major role for demographic factors. Categorical data, such as gender or geographical background, was coded 0 and 1. Cases yielding residuals outside three standard deviations were excluded from the analysis, except in one study as noted in the results. Residual scatterplots and normal probability plots were investigated to ensure normality, linearity and homoscedasticity, as per the assumptions of employing regression (Tabachnick & Fidell, 1996).

Two key figures resulted from the regression analysis. One, adjusted R Square values gave an indication of how much of the variance in motivation was explained by the motivational features and demographics. Two, regression beta coefficients showed which independent variables were significant predictors of motivational outcomes,

then of those, what their relative strength was by comparing standardised beta values. Much of the analysis is based on these statistics.

4.7.3. Statistical analysis – sub-questions

To answer the sub-questions, relationships between the motivational features were investigated through correlation, factor and regression analyses. These three methods built on each other to provide a fuller picture of relationships. Correlation between motivational features provided a general overview of associations. Factor analysis built on correlation data, as it identified groups of correlated items, and importantly allowed one to see which individual items were involved. Seeing the role of individual items within group hierarchies allowed finer interpretation of relationships between groups than viewing individual item correlation tables. Factor analysis also provided data on relationships between motivational features (usually discrete factors), including which variables were independent of each other based on factor loadings, and which items within the factors/scales may be involved in relationships (i.e. via co-loading, or changing factor groupings as variables are pared back).

Regression was used in much the same way as in answering the main research questions, however motivational features were both dependent and independent variables. The same process with treatment of residuals and data output was employed. Regression beta values showed more definitively which motivational features are related (i.e. significantly predict each other) and, importantly, which were unrelated and hence are likely to work independently. Beta values also provided a relative measure of relationship strength when one motivational feature was related to several others. R Square results showed how much variance was associated with other motivational features overall, or the general overlap of features.

Only the data set from the *Burning Issues* general public shows was used to address the sub-questions. This data set was used as, critically, it was the only data set that contained all the individual variables involved in the sub-questions. Moreover, this data set had a large (N = 407), diverse sample containing young children, parents, teenagers and young adults, and adults out of a family context – these characteristics were unique to this sample. The show was also not presented by the researcher, meaning the motivational features studied were not biased by background knowledge and used in a more 'natural' fashion. Because of these characteristics, results are more likely to be generalisable to a wide range of audiences and presenters. This makes it both the only and most suitable data set to work with for the sub-questions.

4.8. Limitations of the method

Several limitations of the method should be noted and can be divided into issues concerning: survey data collection methods (including both the participant's responses and the design of the survey instruments); statistical analysis; and evidence of causality.

While surveys have many advantages, as outlined earlier, they also carry limitations. Social desirability, leniency, acquiescence and transient mood states are all potential sources of bias in participants' responses. Socially desirable responses describe the tendency for people to present themselves in a favourable, socially-acceptable way regardless of the truth (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Singleton & Straits, 2005). This kind of bias may be conscious and deliberate or unconscious self-deception. Social desirability bias may be present in responses to questions about understanding content, where people may want to appear competent. It is likely to be a bigger issue in responses to questions about motivation, attitudes and especially

behavioural intentions (e.g. in the climate change and HIV research presented here). This also raises a related limitation, in that people's behavioural intentions, while indicative, do not represent their actual behaviour (Singleton & Straits, 2005).

Leniency bias describes when a participant attributes socially desirable characteristics to someone they know and like (Podsakoff et al., 2003). As presenters actively try to build rapport with audiences, even the short interaction during a show may be enough to build a personal liking and hence bias. It is likely this bias played a role In questions asking opinions of the presenter (i.e. immediacy items) and to a lesser extent the show itself, where people may want to give a 'nice' answer. In certain studies, the audiences were aware the presenter was also the researcher, which may further inflate leniency bias.

Acquiescence is when a participant either tends to consistently agree or disagree with statements, regardless of content, making Likert scales particularly vulnerable (Podsakoff et al., 2003; Singleton Jr. & Straits, 2005). In the context of this research, which primarily used positively worded questions, acquiescence may also lead to artifactual covariance between constructs and spurious relationships (Winkler, Kanouse, and Ware (1982) cited in Podsakoff et al., 2003).

The transient mood state of participants will affect their responses. While any number of factors outside of the show context may play a role in influencing transient mood, the fact that a show aims to provide a positive experience and provoke positive emotions may 'produce artifactual covariance in self-report measures because the person responds to questions about both the predictor and criterion variable while in a particular mood' (Podsakoff et al., 2003, p. 883).

Limitations inherent in the design of the survey instrument relate to the ways items influence one another and scales used for measurement. Item context effects describe how items in a survey influence interpretation of other items in the survey. According to Podsakoff and coauthors (2003) these include, for example, that asking one question may make answers to another more salient (item priming); neutrally worded items may take on the context of surrounding items (item embeddedness); and the tone and mood set by initial questions may influence how the rest of a survey is completed (context-induced mood). All these effects are likely to have somewhat influenced responses in these studies.

Item priming, however, is especially relevant as it has implications for the use of scales to measure overarching constructs. For example, if people are asked if they liked the show presenter this will focus thoughts on the presenter, which may in turn influence evaluations of how enthusiastic one thought the presenter was – both items that measure immediacy. Moreover, this effect is likely to be stronger in relatively short survey instruments (as used here), as participants still have their answers in short-term memory. This makes similarities between scale items more noticeable, increasing artifactual correlation (D. E. Harrison, McLaughlin, & Coalter, 1996). This appears to be somewhat of a 'catch 22', as the negative outcome is a degree of artifactual covariance between the items (and inflation of scale reliabilities), however on the other hand shows that the scale items have convergent and content validity.

If one extrapolates the way items can influence one another to the scale/construct level, especially when similar scale/constructs are being investigated such as interest, curiosity and motivation, it is also possible that intermixing constructs may produce artifactual covariation among the constructs (Podsakoff et al., 2003). In the context of

the statistical analysis used here, this may inflate the strength of relationships shown in regression analyses. That is, as a series of questions related to interest and curiosity are asked, followed by a series on motivation, part of the covariance in answers will be due to the actual relationship between these constructs, however part may also be due to item- or scale-priming effects.

Although the use of factor analysis to refine scales improved reliability, the statistical analysis that underpinned this was subject to limitations. To be most robust, scales should be initially created and tested with one sample using exploratory factor analysis, then refined and tested on another sample and analysed using confirmatory factor analysis (e.g. Linnenbrink-Garcia et al., 2010). Then the scales are ready for use in other research. The limited numbers of shows available and limitations inherent in a PhD project meant that these three steps were rolled into one, however this issue was somewhat mitigated by reuse of scales and items from study to study. Moreover, in an ideal world, any items showing salient co-loading (non-independence) on two factors/scales would be dropped and new items tested until no co-loading occurred. Again, limited numbers of shows and overall time meant this was not possible, however co-loading was minimised as much as possible through dropping items.

Inferring causality is a final limitation of the method due to the non-experimental nature of the shows and the explanatory survey data, which ultimately only shows association between variables. This is a common issue in social research, as highlighted by Singleton and Straits (2005):

> Beyond association between variables, the criteria for inferring cause-and-effect cannot be established as easily in surveys as in experiments. For example, the criterion of directionality – that

> a cause must influence its effect – is predetermined in experiments by first manipulating the independent (or causal) variable and then observing variation in the dependent (or effect) variable. But in most surveys this is often a matter of interpretation, since variables are measured in a single point in time. (Singleton & Straits, 2005, p. 227)

The shows studied here are not 'experiments' *per se*, and variables (such as enthusiasm) while consciously used are not accurately controlled or objectively measurable, i.e. enthusiasm can not be set at level 2 for one show and level 5 for another and the effects on motivation measured. This is unavoidable in an authentic science show (which is important for reasons outlined earlier) and the ethics of deliberately performing, for example, unenthusiastically when people are attending in a free-choice authentic context are questionable. Even if it were attempted, the subjective nature of many variables studied here (e.g. value and enthusiasm) would make experiments highly problematic, although not impossible.

As raised above, establishing cause-and-effect relationships and directionality is an issue in non-experimental approaches. Many of the studies described in this work involved only post-show surveys. It is reasonable to argue that response to the show (e.g. arousing emotions) will affect the outcomes of that show (e.g. motivation), as the response to the show must precede any outcomes. Therefore emotional arousal is the cause and motivational outcomes the effect, which is the assumption made here. While less likely it is, however, also possible that people that find a science show highly motivating (for any number of reasons) will then find that show more emotionally arousing; cause and effect are reversed. Moreover, the statistical method of regression used here does not give proof of causality or directionality; it is based on correlation and association. The assumption made in this work is that the motivational features

(e.g. value, immediacy, etc.) cause effects on motivational outcomes or motivational change. The reality, while beyond the scope of this work, is that there is likely to be a bidirectional relationship amongst some variables.

The studies described here did not use control groups, which is another limitation to inferring causality. Given the shows were one-off stand-alone events primarily attended in free-choice contexts, establishing a control group is difficult. For example, in science show research by Caleon and Subramaniam (2007) where the show was a prearranged excursion that formed part of a series of activities, the whole group was given an attitude pretest survey one week before, then groups were split and the control group was given the posttest before the show, while the experimental group was given it after the show. Then both groups were given a delayed posttest two weeks afterwards. This method isolated the effect of the show in the experimental group. Approaches such as this were not practical for this research, mainly because the majority of studies involved the general public attending one-off events in free-choice contexts. This meant the usual approaches to control groups – e.g. giving them a different activity or surveying them at different times in a series of prearranged activities (as per Caleon and Subramaniam's method) – were not possible.

4.9. Summary

This chapter has outlined the methods used in this thesis and the reasons they were adopted. The studies were based on quantitative survey data, which was the most suitable approach given previous research and the research questions. The general method was repeated across a number of studies, each varying aspects such as the show, presenter, audience, venue and mix of variables investigated. This approach improves confidence in overall findings. The shows that were described in this chapter

can be broken into two categories based on their motivational aims: (1) shows with subtle motivational outcomes, such as influencing attitudes to science; and (2) shows with overt motivational outcomes, which aim to influence specific behaviours.

The process and considerations of creating the survey instrument, data collection methods and statistical analysis were outlined. Key aspects included steps in item creation and creating concrete items for studies investigating overt motivational outcomes, how these items were arranged into scales, and describing the make up of the scales – including using appraisals and underlying components in measurement. Data collection procedures were outlined, including the two main designs: post-only and pre-post (which gives a score for motivation change). Major stages of data processing and statistical analyses included: using factor analysis to inform scale development and determine less reliable items that may be dropped; calculating scale scores for the motivational features and motivation; and, for pre-post designs, calculating motivation change scores and testing for significant differences between pre- and post-. Regression analysis was then used to determine association between motivation or motivation change (dependent variable), and the motivational features and demographics (independent/predictor variables).

The next chapter reports results of this method, primarily the samples, scales, and regression analyses. Studies are divided into shows with subtle or overt motivational outcomes.

Chapter 5. Results

5.1. Overview

This chapter focuses on the main research question posed in this work – What features of a science show motivate people? – along with a section addressing the sub-questions. In line with previous chapters, the main research question is broken down into asking (1) do shows motivate people, and if so, (2) are the identified motivational features associated with motivation? To address part one of the question, scores for motivational outcomes are assessed. In all studies, measurement of motivational outcomes aimed to capture changes due to the show. Studies that used a pre-post design most accurately measure these changes. Final scores in post-only designs, where wording was used to focus participants on change, also provide an indication of the motivational impact.

Part two of the question will be answered by regression results showing the relationship between demographics and motivational features (independent variables) and motivational outcomes/change (dependent variable). For each regression, model statistics are presented to show how much variance in motivational outcomes can be explained by the independent variables. Tables of beta coefficients then show which independent variables are significant predictors and their relative contributions – these are key results for this research. Essential background for each study – sample demographics, show context, and scale statistics – is also included.

As in earlier chapters, studies are split into the kind of motivational outcomes, subtle or overt, that are aimed for in different shows. An overview of the structure of this chapter is presented in Figure 4. Initially three studies on subtly motivational shows

using post-only motivational measures are presented: *Booming for Beginners*, *Questacon Video Conferences* and *Going Ballistics*. Following that are studies on the show *Burning Issues*; these are divided into public shows (post-only measures of subtle motivational outcomes) – which are analysed as three subsamples: all ages (the entire sample), youth and adults – and school shows (pre-post measures of subtle and overt motivational outcomes). I then turn to three studies with overt motivational outcomes: *The Alarming AIDS Adventure*, *Sustainability 2010* and *Sustainability 2011*. All the studies are then compared to draw overall results pertaining to the main research question. This includes summaries of the role of the motivational features, then the role of age and gender.

Figure 4. Overview of the Chapter, including studies presented and the type of motivational outcomes investigated

Lastly, supplementary results relevant to the sub-questions that emerged from the literature review are presented. As noted, these questions relate to relationships

between motivational features, hence correlation, regression and factor analyses are used. These analyses are only conducted on the *Burning Issues* public sample, which had all the variables involved, a large and diverse sample, and other features likely to make the results more generailisable (see section 4.7.3.).

5.1.1. Conventions and general notes on results

Several formatting conventions are adopted in this section. This PhD research is made up of data sets from different shows, which are each referred to as a *study* or collectively as *studies*. In this and following chapters, study titles have been shortened and are italicised, e.g. *Booming*.

Tables of regression beta coefficients are listed in order of magnitude of the standardised beta value to allow easy comparison, with non-significant predictors shaded grey. Any predictors with significant and negative beta values are listed at the bottom, under the grey shaded section, to highlight the inverse effect. All scale scores used for regression are standardised (summed and then divided by the number of items in the scale, giving a score out of five), except in pre-post designs where motivation change is the exact amount of change (note the regression procedure standardises beta coefficients in this case anyway). In all regression analyses, gender is coded males = 1, females = 0, meaning significant positive beta values for gender indicate being male predicted motivational outcomes or change.

Note tables of demographics may not always tally exactly due to missing values in age and/or gender. Missing values for gender but not age are shown in tables. Histograms and youth/adult splits are shown for general public audiences only. Scales or other composite item measures (e.g. motivation change) within tables are in capitals,

whereas single items and demographic variables are in lower case. Non-significant values for all statistical tests are shaded grey (as with non-significant predictors in regression findings).

Copies of item wordings, items in each scale, notes on scale characteristics and development, and survey instruments can be found in Appendix A and B.

5.2. Shows with subtle motivational outcomes

5.2.1. Booming for Beginners (Booming)

This study was completed early in the PhD project as a pilot study, hence many aspects were still in development. Scales for value, surprise, curiosity and immediacy were significantly refined following this study, which highlighted item wording and survey formatting issues. Nevertheless, as the data supports broader conclusions from other studies and shows the development process, it is included here.

Sample

The sample was collected over two performances of the same show *Booming for Beginners* during National Science Week, performed at the CSIRO Discovery Centre (a science focused public venue) in Canberra, Australia. Audiences attended free-of-charge in a free-choice context. I wrote and performed the shows.

Table 3. *Booming*: gender by age

		N	Age	
			≤ 18 (youth)	> 18 (adults)
Gender	?	20	7	13
	F	57	35	22
	M	60	42	18
Total		137	84	53

Age data was collected in categories for this study only. M and SD are not available.

Most audience members attended in family groups, as reflected by the split of youth and adults shown in Table 3. There were approximately equivalent numbers of males and females and a broad spread of ages, ranging from younger than five to older than 50 (note age data was collected in categories for this study only, however is reported as above to be consistent with other studies). No 17 to 20 year olds were amongst the sample, and in general the 14 to 30 age group were underrepresented (which is a common anecdotal observation with shows and events of this nature). Age distribution is shown in Figure 5.

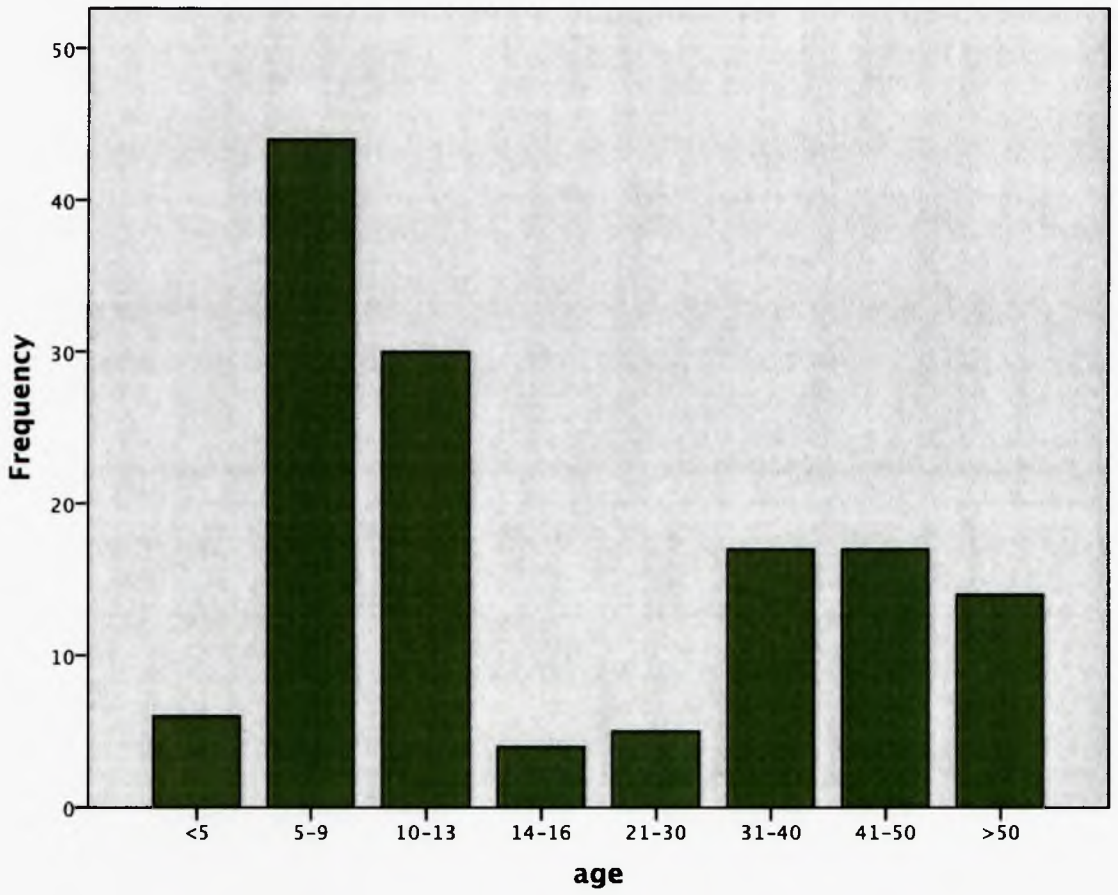

Figure 5. *Booming*: age

(Note the 17-20 category that was empty is not shown.)

Scales

Table 4. *Booming*: scale scores and reliabilities

	N	Mean	SD	# items	Cronbach's alpha
INTEREST-ENJOYMENT	135	4.60	0.47	5	0.799
IMMEDIACY	138	4.23	0.58	3	0.666
MOTIVATION	132	4.14	0.57	4	0.739
SURPRISE-CURIOSITY	137	4.15	0.57	4	0.671
VALUE	128	4.05	0.57	3	0.602

As with some other studies, factor analysis showed that interest and enjoyment items and surprise and curiosity items formed discrete factors, in line with their close associations noted in the literature, and hence they were combined.

Table 4 shows that reliabilities were adequate for some scales, however Cronbach's alphas for immediacy, surprise-curiosity and in particular value were slightly lower than desirable. Given the pilot nature of the study and the early stage in the overall research, these scales were still used. They were, however, earmarked for further refinement of item wording and, in particular, development of additional items as Cronbach's alpha is sensitive to the number of items in a scale. Moreover, an item was dropped from the surprise-curiosity scale that lowered Cronbach's alpha from 0.730 to 0.671 because it co-loaded on the motivation factor. While it lowered reliability, leaving the item would have falsely inflated the effect of surprise-curiosity in regression analyses.

Mean scale scores were all above 4, demonstrating the show is engaging the emotions and motivational variables under study (and also possibly some ceiling-effects in the survey instrument). The mean score for motivation indicated most people agreed or strongly agreed with the motivational outcome items. The subtle motivational

outcomes that made up this scale were less concrete and specific regarding actual behaviours, and more targeted towards general dispositions like information-seeking and positive attitudes towards science.

What influenced motivational outcomes?

Scores for interest-enjoyment, immediacy, surprise-curiosity and value, along with age and gender, were regressed on motivational outcomes. Overall, the model explained 45% of the variance in motivational outcomes, $R^{2\ adj.} = 0.452$, $F(6,98) = 15.28$, $p < 0.001$.

Table 5. *Booming*: regression onto motivational outcomes

	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.79	0.46		1.71	0.091
VALUE	0.31	0.09	0.32	3.60	0.001
SURPRISE-CURIOSITY	0.20	0.08	0.21	2.44	0.016
Gender	0.19	0.08	0.17	2.33	0.022
IMMEDIACY	**0.16**	**0.08**	**0.17**	**1.86**	**0.066**
INTEREST-ENJOYMENT	**0.17**	**0.11**	**0.14**	**1.59**	**0.114**
Age	-0.05	0.02	-0.27	-3.44	0.001

Comparing beta coefficients, as shown in Table 5, shows value most strongly predicted motivational outcomes (the highest beta value). Age had a strong inverse effect, with motivational outcomes declining with age. The motivational outcomes of adults (age > 18; M = 3.95, SD = 0.49) were significantly lower than those of youth (age ≤ 18; M = 4.21, SD = 0.60); $t(123) = 2.54$, $p = 0.012$. Surprise-curiosity positively predicted motivational outcomes, however its effect was about two thirds that of value. Finally, being male significantly predicted greater motivational outcomes; although males (M = 4.21, SD = 0.51) had higher motivational outcomes than females (M = 4.02, SD = 0.64) a t-test found no significant difference between them. This finding, in combination with gender's beta value significance (0.022) being close to the 0.05 significance

threshold, means the effects of gender are minor. Neither interest-enjoyment nor immediacy predicted motivational outcomes. In sum, this study showed that value, surprise-curiosity and age (inversely), and to a lesser extent being male, were all associated with higher motivational outcomes.

5.2.2. Questacon Video Conferences (QVC)

Sample

This data set comprises seven different shows performed in 14 different schools over a two-week period. In contrast to other shows studied here, the shows were performed via video conference, although still allowed audience and presenter to interact. Each show followed the same general format using demonstrations and multimedia (still images, effects and sometimes videos), however covered broad topics including forensics, cell and animal biology, physics and earth sciences. The shows were offered free-of-charge to students in rural and regional primary schools in New South Wales, Australia. The shows were created and performed by students in the Shell Questacon Science Circus, a postgraduate course run by Questacon – The Australian National Science and Technology Centre and The Australian National Centre for the Public Awareness of Science, Australian National University. The data sets were collected on behalf of Questacon. The author had no input into the shows.

Table 6. *QVC*: gender by age

		N	Age	
			M	SD
Gender	F	372	10.46	1.24
	M	406	10.11	1.54
Total		772	10.28	1.42

A large sample was created by combining the various performances, with roughly equivalent numbers of males and females, as shown in Table 6. Ages were tightly clustered around 10 years old, reflecting a majority of upper primary school audiences. In this and subsequent studies, people simply wrote their age rather than selected categories as in the previous study.

Scales

Table 7. *QVC*: scale and item scores and reliabilities

	N	M	SD	# items	Cronbach's alpha
CURIOSITY	740	3.06	0.95	3	0.659
HANDSON	758	3.32	1.10	2	0.672
IMMEDIACY	714	3.62	0.80	7	0.812
INTEREST-ENJOYMENT	738	3.85	0.80	5	0.771
MOTIVATION	734	3.41	1.01	4	0.846
Pictures-videos	766	3.76	1.11	1	NA
REALWORLD	750	3.66	0.84	2	0.555
Screen-good	770	3.06	1.33	1	NA
SURPRISE	710	3.74	0.89	3	0.680

Scale reliabilities (see Table 7) were excellent for motivational outcomes, and fairly good for interest-enjoyment and immediacy (improved by using seven items in contrast to three in the previous study). Three of the original seven items were dropped from the motivational outcomes scale as they co-loaded onto other factors, primarily immediacy. Cronbach's alphas for curiosity and surprise, however, were slightly less than desirable, indicating more development and/or scale items were required. Both two-item scales (handson and realworld) were below the 0.7 reliability threshold, however given the sensitivity of Cronbach's alpha to the number of items in a scale these scales were still used. Handson in particular was retained as this measured the effects of in-school hands-on activities facilitated via the video link – a unique interactive aspect of the shows that I hypothesised could have a strong effect.

While I was initially briefed that most shows would use in-class activities like this, very few actually did. This needs to be considered when interpreting results (handson had no influence on motivational outcomes, though may have had more shows used in-class activities). The motivational outcomes scale used was primarily subtle, relating to information-seeking and positive attitudes to science, however it also contained an item on studying science at high school. Two single-item measures, pictures-videos and screen-good, measured the use of visual effects and quality of the video link respectively. These aspects were important to the video conference format and simple enough to measure reasonably accurately in a single item, so they were included despite reliability problems when using single item measures in regression analyses.

Standardised scores ranged between 3 and 4, with the motivational outcomes score slightly lower than other post-only studies of subtle outcomes. The average score for screen-good of approximately 3 (neutral on a Likert scale) and comparatively high standard deviation indicates that audio-visual or other video conference connection problems were reasonably common.

What influenced motivational outcomes?

All independent variables were regressed onto motivational outcomes in a two-stage hierarchical model including: (1) motivational features and demographics (to allow these to be directly compared with other studies); and, (2) with the addition of pictures-videos and screen-good. Model one explained 59% of the variance, $R^{2\ adj.} = 0.588$, $F(8,649) = 118.28$, $p < 0.001$, with model two explaining about 1% more, $R^{2\ adj.} = 0.608$, $F(10,647) = 100.26$, $p < 0.001$. Both variables specific to the video conference (added in model two) were significant predictors of motivational outcomes, indicating

good a quality connection and clear picture (screen-good) were associated with motivation.

To allow comparison with other studies and focus on key variables, the following description regards model one. In contrast to all but one other study, immediacy significantly predicted motivational outcomes and had the greatest single influence (beta coefficients are shown in Table 8). Note the immediacy scale included a comparatively high number of items (four of seven) tapping interactivity and involvement (sustained SI 'hold' factors; Mitchell, 1993), as these elements were thought to be more critical in the somewhat disconnected medium of the video conference.

Table 8. *QVC*: regression onto motivational outcomes

Model		Unstandardised Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-0.34	0.29		-1.15	0.249
	IMMEDIACY	0.42	0.05	0.33	8.14	0.000
	SURPRISE	0.24	0.04	0.21	6.55	0.000
	REALWORLD	0.19	0.04	0.16	4.78	0.000
	INTEREST-ENJOYMENT	0.19	0.05	0.15	3.61	0.000
	CURIOSITY	0.13	0.03	0.12	4.10	0.000
	Gender	**0.05**	**0.05**	**0.02**	**0.95**	**0.344**
	HANDSON	**-0.02**	**0.03**	**-0.03**	**-0.83**	**0.405**
	Age	-0.04	0.02	-0.06	-2.20	0.028
2	(Constant)	-0.29	0.29		-0.99	0.323
	IMMEDIACY	0.32	0.06	0.25	5.83	0.000
	SURPRISE	0.21	0.04	0.19	5.82	0.000
	REALWORLD	0.17	0.04	0.14	4.24	0.000
	INTEREST-ENJOYMENT	0.18	0.05	0.14	3.40	0.001
	Screen good	0.10	0.03	0.13	4.06	0.000
	CURIOSITY	0.12	0.03	0.11	3.95	0.000
	Pictures videos	0.07	0.03	0.07	2.47	0.014
	Gender	**0.04**	**0.05**	**0.02**	**0.72**	**0.473**
	HANDSON	**-0.03**	**0.03**	**-0.04**	**-1.21**	**0.229**
	Age	-0.04	0.02	-0.05	-1.95	0.052

Surprise, realworld, interest-enjoyment and curiosity (in order of beta value) also predicted motivation, with beta values half to two-thirds that of immediacy. As with other studies an inverse effect was found for age, however in this student sample where age was tightly grouped the beta value was smaller than most other studies and of borderline significance ($p = 0.052$). Nevertheless, the model suggests that the older one is, the less one is motivated. In summary, this study showed that immediacy can indeed be a motivational variable, at least with this audience and video conference medium, however all other main motivational variables except handson also predicted motivational outcomes – particularly surprise.

5.2.3. Going Ballistics (Ballistics)

Sample

This data set is made up of three shows, two performances of *Booming for Beginners* and one of *Going Ballistics* (though is referred to collectively as *Ballistics* to differentiate it from the first study). The shows were similar in content, presenter, audiences and contexts, hence were combined. Two shows were presented in science-related contexts as part of the Australian Science Festival and National Science Week, whereas one was presented for Father's Day. All were presented in science-related venues (CSIRO Discovery and the Australian Academy of Science). Audiences attended in a free-of-charge, free-choice context. I wrote and performed the shows. The shows included several discrepant events, as discussed in section 3.1.1..

Table 9. *Ballistics*: gender by age

		N	Age			
			≤ 18 (youth)	> 18 (adults)	M	SD
Gender	?	4		2	42.00	5.66
	F	64	27	37	27.89	17.15
	M	79	45	29	22.70	17.33
Total		147	72	68	25.35	17.38

Table 9 shows age and gender data for the sample. Family groups made up most of the audience, with ages ranging from 4 to 73. Approximately equivalent numbers of youth and adults attended, however comparatively few attendees were aged 20 to 30 or 50 and over (see Figure 6). As with most audiences studied here, gender was approximately equally divided, slightly favouring males.

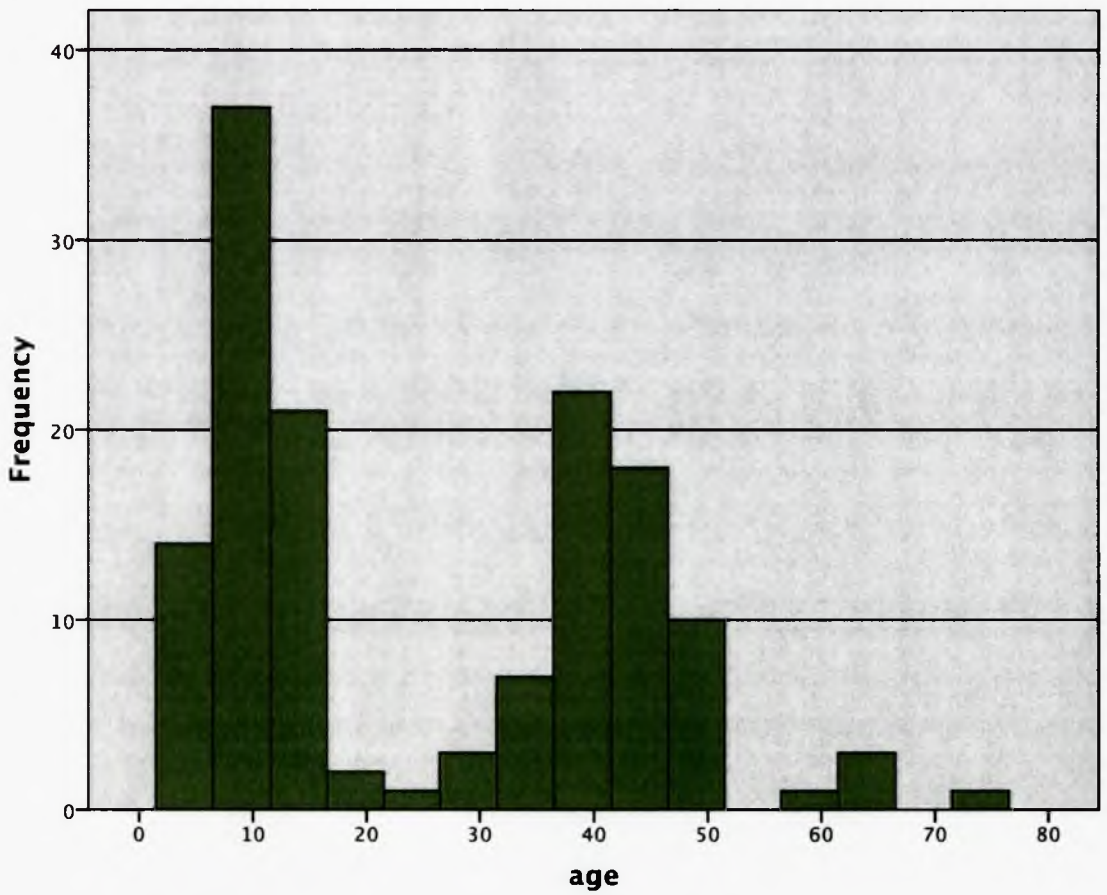

Figure 6. *Ballistics*: age

Scales

Table 10. *Ballistics*: scale scores and reliabilities

	N	M	SD	# items	Cronbach's alpha
CURIOSITY	132	3.68	0.73	4	0.782
IMMEDIACY	134	4.58	0.43	7	0.805
INTEREST-ENJOYMENT	132	4.46	0.47	7	0.824
MOTIVATION	134	3.96	0.64	5	0.852
REALWORLD	134	4.25	0.67	2	0.596
SURPRISE	133	3.76	0.82	4	0.799

Scales in this study showed greater reliability than previous studies, as listed in Table 10. With the exception of realworld, which was retained despite low reliability as it was a two-item scale, all scales showed good reliability most likely due to additional items and honing of item wording. One item tapping 'being more excited about science' was dropped from the motivation scale as it co-loaded on the surprise factor. Consistent with other shows in the subtle category, the motivational outcomes scale used was focused primarily on general dispositions to science and to a lesser extent on information-seeking following the show.

Mean scores (see Table 10) indicated the show was well received by the audience, in particular the levels of immediacy and interest-enjoyment. A mean motivation score of 3.96, along with low standard deviation and high scale reliability, indicates most of the audience found the show motivating across the different measures used in the scale.

What influenced motivational outcomes?

Regression of the independent variables onto motivational outcomes gave a model which accounted for 57% of the variance, $R^{2\ adj.} = 0.571$, $F(7,119) = 24.83$, $p < 0.001$. As shown in Table 11, curiosity and surprise were the largest predictors of motivational outcomes and had a similar magnitude for beta, followed by interest-enjoyment.

Surprise and curiosity's relative strength compared to interest-enjoyment was higher in this study, which investigated shows featuring discrepant events. Immediacy did not predict motivation, which is consistent with results for other shows presented to family audiences. In contrast to *QVC*, realworld (a depersonalised form of value looking only at real world links) did not predict motivation. Gender had no significant effect. Once again, age had an inverse effect – in family audiences adults experience less motivation than youth, with motivation declining with age, even when scales are designed to be applicable to both. In sum, motivation was predicted most strongly by curiosity and surprise, and to a lesser extent by interest-enjoyment and age (inverse effect).

Table 11. *Ballistics*: regression onto motivational outcomes

	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-0.10	0.43		-0.23	0.816
CURIOSITY	0.26	0.07	0.29	3.78	0.000
SURPRISE	0.20	0.07	0.26	3.04	0.003
INTEREST-ENJOYMENT	0.25	0.11	0.18	2.23	0.028
IMMEDIACY	**0.22**	**0.12**	**0.14**	**1.77**	**0.079**
Gender	**0.12**	**0.08**	**0.09**	**1.55**	**0.125**
REALWORLD	**0.09**	**0.08**	**0.09**	**1.15**	**0.253**
Age	-0.01	0.00	-0.16	-2.15	0.033

5.3. Same show; subtle and overt outcomes

This section looks at the show *Burning Issues*, which was presented separately to the general public and to secondary school students. For the latter audience subtle messages were included which may have had the potential to sway students' opinions of chemistry. These messages included things like mentioning school chemistry/science several times during shows, hosting the shows in a university chemistry lecture theatre, having the university clearly branded and represented,

showing an exciting view of the work of a chemist, and – to a degree – allowing this research to be conducted both before and after shows. Nevertheless, the shows were not a blatant 'advertisement' for chemistry study and careers. This begs the question, would the show influence overt motivational outcomes such as future study or spending free time learning chemistry? While some of the messages noted above featured in the general public shows, which were performed in a general lecture theatre, there was a discernibly broader pitch. This was appropriate for the audience which spanned young children through to chemistry boffins.

The following studies first look at the public shows, where subtle outcomes were measured in accordance with the mixed age audience using a post-only design. The public sample was large enough to analyse as three subsamples comprising all ages (the total sample), youth and adults, which facilitated comparisons of which variables were motivational in different audience segments. Data for each subsample is presented then the three compared. School shows results are then presented, where subtle and overt motivations were measured using a pre-post design. The comparison of public and school studies allows observations regarding the degree to which the regression models explained (R Square values) subtle compared to overt outcomes, and free-choice versus non free-choice settings.

5.3.1. Burning Issues Public Shows (Burning Public)

Sample

The data presented here is from two public performances of *Burning Issues*. The shows were presented in a general educational setting at the Australian National University. Audiences attended in a free-of-charge, free-choice context. I had no detailed prior knowledge of the shows nor input into them. Compared to *Ballistics* and *Booming*

(shows I presented), *Burning Issues* contained fewer discrepant events. The presentation of these discrepant events made minimal use of structured ways to highlight discrepancy and enhance counterintuition, such as presenting the demonstration in two contrasting steps, as used in *Ballistics* and *Booming*. These factors appear important for interpreting findings.

Table 12. *Burning Public*: gender by age

		N	Age			
			≤ 18 (youth)	> 18 (adults)	M	SD
Gender	?	3	2	1	17.67	2.08
	F	161	55	106	28.16	16.04
	M	243	109	134	26.65	16.80
Total		407	166	241	27.18	16.46

In contrast to previous studies, Table 12 shows *Burning Public*'s audience had far more males, especially male youth. As with other public shows, a broad range of ages from 5 to 75 attended. This included 89 17-to-25 year olds and very few in their 30s (see Figure 7) – which was a stark contrast to most studies presented in this work. Anecdotal observations suggest this was due mainly to university students attending, along with a few young parents. The large data set and diversity of ages allowed three subsamples to be analysed: the entire sample (all ages), ages 18 and under (youth), and greater than 18 (adults).

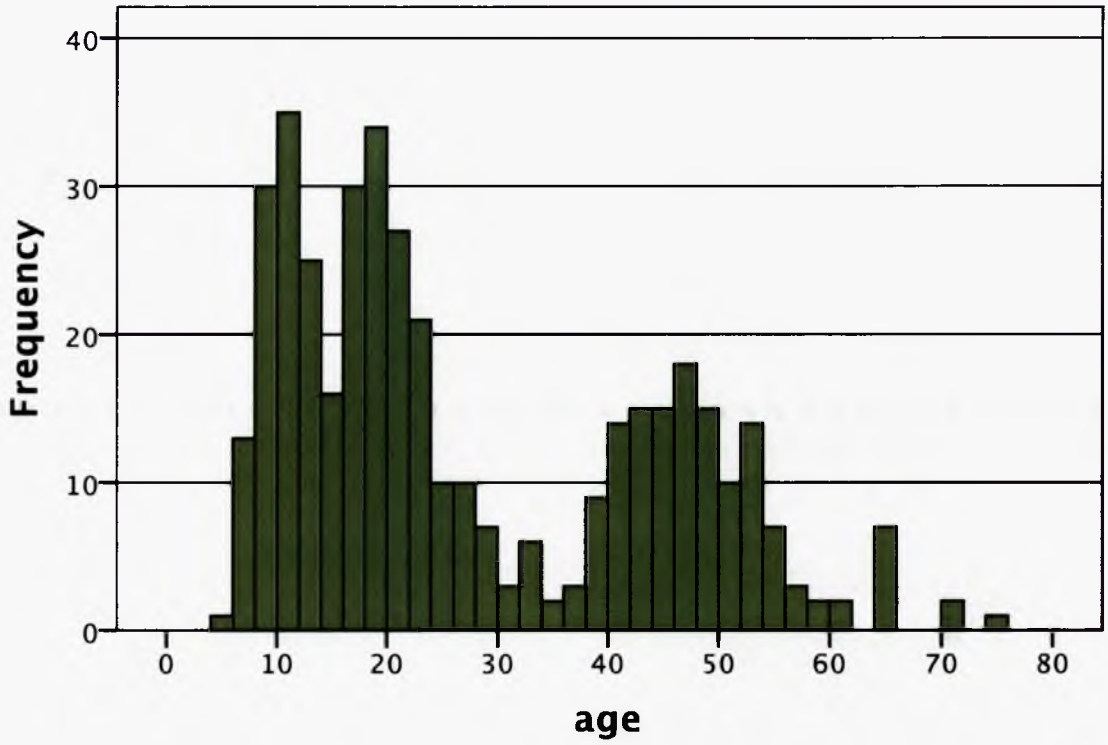

Figure 7. *Burning Public*: age

Scales

As shown in Table 13, all scales showed good reliability, although PEPK was lower than desirable yet acceptable for a two-item scale. Means indicated the show was well received with scores above 4 for immediacy and interest-enjoyment. The show linked to people's PEPK with a mean score just below 4. All other scales, including motivation, were midrange between 3 and 4.

Table 13 shows scores for the motivational features differed significantly between youth and adults. Adults reported greater curiosity, PEPK and immediacy; while youth reported greater motivation and surprise; however value and interest-enjoyment were not significantly different. T-test values indicate the differences are smaller for curiosity and larger for PEPK. Scores show the emotional and motivational experience of youth and adults is distinct across most, but importantly, not all variables.

Table 13. *Burning Public*: scale scores and reliabilities

	All ages / whole sample				≤ 18 (youth)		> 18 (adults)		t-test youth vs. adult	
	M	SD	# items	Cronbach's alpha	M	SD	M	SD	t	p
CURIOSITY	3.51	0.80	3	0.705	3.40	0.85	3.58	0.77	2.09	0.037
IMMEDIACY	4.35	0.45	6	0.705	4.25	0.50	4.41	0.41	3.31	0.001
INTEREST-ENJOYMENT	4.61	0.48	3	0.749	4.64	0.49	4.59	0.48	**-0.917**	**0.360**
MOTIVATION	3.77	0.70	5	0.846	3.91	0.72	3.67	0.68	-3.15	0.002
PEPK	3.87	0.91	2	0.675	3.62	1.05	4.04	0.75	-4.46	0.000
SURPRISE	3.72	0.80	3	0.764	3.83	0.78	3.62	0.81	-2.77	0.006
VALUE	3.77	0.64	6	0.797	3.72	0.68	3.80	0.62	**1.15**	**0.253**

* df = 268-401 including missing values and adjusting for equal variances where necessary

What influenced motivational outcomes?

All independent variables and demographics were regressed on motivational outcomes. The model explained 49% of the variance in motivational outcomes, $R^{2\ adj.} = 0.492$, $F(8,350) = 44.38$, $p < 0.001$. Beta coefficients and significance levels are shown in Table 14. Value was by far the largest predictor, with a beta value approximately threefold that of the next largest predictor, interest-enjoyment. Surprise also predicted motivational outcomes, however surprise had a lower beta value than other studies reported so far. A negative beta value shows PEPK had an inverse relationship with motivation; the greater people's PEPK the less motivation they reported. The result for PEPK was somewhat unusual as the correlation between PEPK and motivation was negligible ($r = 0.031$, non-significant). Gender had a small yet significant effect with being male predicting greater motivational outcomes. As with other studies, age had an inverse role with motivation decreasing with age. Curiosity and immediacy were not significant predictors in the all ages sample. This was not the case, however, in the youth and adults subsamples.

Table 14. *Burning Public*, all ages: regression onto motivational outcomes

	Unstandardised Coefficients		Standardised Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	-0.45	0.31		-0.15	0.885
VALUE	0.58	0.05	0.54	10.83	0.000
INTEREST-ENJOYMENT	0.24	0.07	0.17	3.51	0.001
SURPRISE	0.10	0.04	0.12	2.55	0.011
Gender	0.13	0.06	0.09	2.29	0.023
IMMEDIACY	**0.11**	**0.08**	**0.07**	**1.44**	**0.152**
CURIOSITY	**0.06**	**0.04**	**0.07**	**1.45**	**0.148**
Age	-0.01	0.00	-0.13	-3.28	0.001
PEPK	-0.12	0.00	-0.16	-3.49	0.001

Table 15 and Table 16 show beta values for motivational features and demographic characteristics that predicted motivational outcomes in adults and youth. The models explained a similar amount of variance as with the combined sample, 48% for adults and 55% for youth (adults $R^{2\ adj.} = 0.480$, $F(8,203) = 25.34$, $p < 0.001$; youth $R^{2\ adj.} = 0.554$, $F(8,127) = 21.96$, $p < 0.001$). Value had the strongest effect and was the only variable that predicted motivation in both youth and adults. For adults, curiosity was the only other variable that predicted motivation, however for youth interest-enjoyment, immediacy, gender and age all played a role. Immediacy's effect on youth is consistent with findings from *QVC*. As with previous studies, motivation declined with age in both all ages and youth samples, but not adults, showing youth accounted for most of age's effect. Gender followed the same pattern – being male predicted higher motivation in the all ages and youth samples, but not adults – again suggesting gender effects are limited to youth. Note that PEPK and surprise, which predicted motivation in the all ages sample, did not predict motivation when adults and youth were investigated separately.

Table 15. *Burning Public*, adults: regression onto motivational outcomes

	Unstandardised Coefficients		Standardised Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-0.32	0.42		-0.77	0.444
VALUE	0.55	0.08	0.50	7.07	0.000
CURIOSITY	0.21	0.06	0.23	3.68	0.000
INTEREST-ENJOYMENT	0.10	0.09	0.07	1.07	0.284
SURPRISE	0.05	0.05	0.06	1.01	0.314
IMMEDIACY	0.09	0.11	0.05	0.80	0.427
Gender	0.04	0.07	0.03	0.53	0.598
Age	0.00	0.00	-0.03	-0.66	0.511
PEPK	-0.09	0.05	-0.10	-1.64	0.103

Table 16. *Burning Public*, youth: regression onto motivational outcomes

	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-0.59	0.49		-1.20	0.232
VALUE	0.56	0.08	0.53	7.25	0.000
INTEREST-ENJOYMENT	0.36	0.10	0.24	3.62	0.000
IMMEDIACY	0.28	0.11	0.19	2.59	0.011
Gender	0.25	0.09	0.16	2.66	0.009
SURPRISE	**0.09**	**0.06**	**0.09**	**1.36**	**0.177**
PEPK	**-0.05**	**0.06**	**-0.07**	**-0.89**	**0.377**
CURIOSITY	**-0.06**	**0.06**	**-0.07**	**-1.07**	**0.286**
Age	-0.05	0.01	-0.23	-3.18	0.002

Figure 8 shows beta values and significance of predictors in different groups. In sum, value was the only variable that predicted motivation in youth, adults and the all ages sample. Other variables did not have such widespread effects: curiosity only predicted motivation in adults; immediacy only predicted motivation in youth; whereas interest-enjoyment, age (inverse relationship) and gender predicted motivation in youth and all ages samples. Beta values for interest-enjoyment, gender and age were largest in the youth sample, comparatively smaller in the all ages sample, and non-significant in the adult sample. Hence youth accounted for most of these effects in the all ages sample. PEPK (inverse relationship) and surprise were only predictors in the all ages sample. These differences will be discussed in the next chapter. To interpret these findings, correlations between surprise and curiosity in the different groups are useful: youth ($r = 0.311$), all ages ($r = 0.398$), adults ($r = 0.498$), all significant $p = 0.000$. The correlation between surprise and curiosity increased with age. Taken together, aside from value, different variables were associated with motivational outcomes in adults and youth.

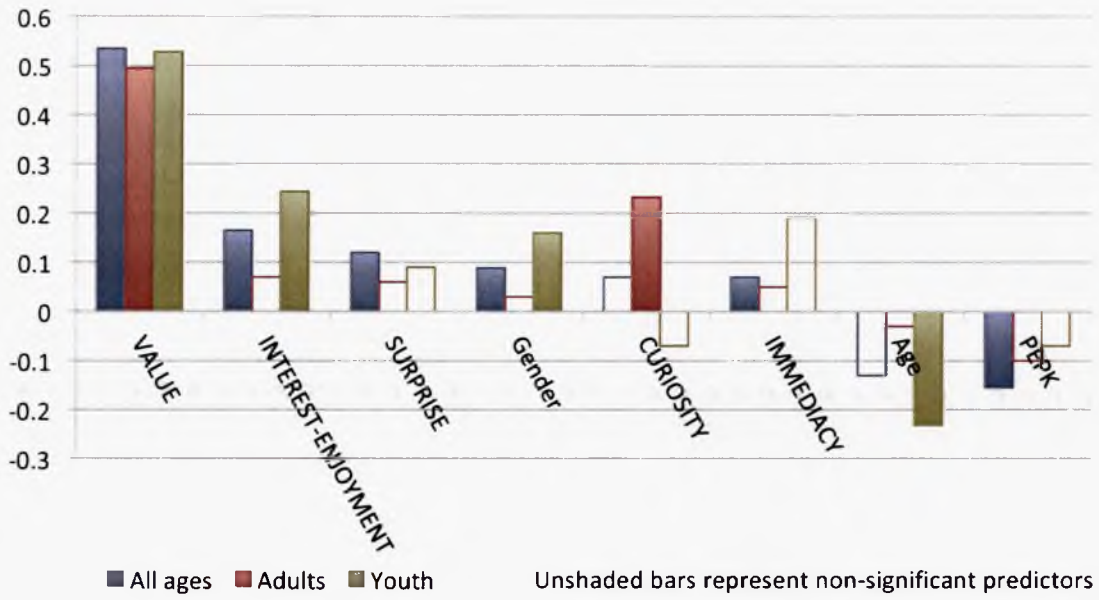

Figure 8. Beta values for predictors of motivation in different groups.

5.3.2. Burning Issues School Shows (Burning Schools)

Sample

The data presented here are from five performances of *Burning Issues* using a pre-post method. Mainly secondary school students in school excursions attended, so this does not represent a free-choice environment, however attendance was free-of-charge. Typically, two to three different schools attended each show. Teachers and other adults were excluded from the analysis as the motivation scale was specifically written for secondary students. Results on motivation changes pre to post are presented at the end of this section.

Table 17. *Burning Schools*: gender by age

		N	Age	
			M	SD
Gender	F	170	14.07	2.00
	M	172	14.21	2.01
Total		342	14.14	2.00

As shown in Table 17, the average age of students was about 14, indicating audience members were predominantly in Year 8 where decisions on elective subjects are often made. The sample contained almost exactly the same number of males and females.

Scales

Table 18. *Burning Schools*: scale and items scores and reliabilities

	N	M	SD	# items	Cronbach's alpha
Confident	317	3.62	1.05	1	NA
Good-marks	315	3.68	0.92	1	NA
IMMEDIACY	318	3.95	0.71	5	0.827
INTEREST-ENJOYMENT	310	4.06	0.63	6	0.836
MOTIVATION CHANGE *	258	1.42	5.02	13	NA
PEPK	321	3.53	0.90	2	0.652
POST-MOTIVATION	294	3.46	0.84	13	0.949
PRE-MOTIVATION	296	3.35	0.85	13	0.948
SURPRISE-CURIOSITY	310	3.54	0.74	4	0.732
VALUE	306	3.45	0.74	6	0.845

* Motivation change score is the sum of pre to post differences across 13 items, see section 4.7.2. for calculation procedure.

Table 18 indicates all scales had acceptable reliability (although below 0.7, PEPK was adequate given it had two items), especially the pre- and post-motivation scales. Three items specific to this study asked about students' experiences in school science/chemistry, as while it was not a focus of the study, it may influence motivation from a show. Two single-item measures 'confident' and 'good-marks' measured students' confidence and results respectively, and students also recorded whether they studied general science, chemistry, neither or had dropped science/chemistry. This latter measure was collapsed into studying general science (n = 238; 70%) and chemistry (n = 52; 15%), as this accounted for all but four of the sample that responded (n = 48; 14% failed to answer the question). Factor analysis in scale development (supported by close associations reported in the literature) suggested that surprise and curiosity items could be combined into a single scale. To put these

findings in context, in contrast to previous studies the motivation scale included numerous concrete and specific items – it measured some overt motivational outcomes such as choosing chemistry/science subjects, studying chemistry at university, and studying chemistry in leisure time.

What influenced motivational change?

Pre-motivation, motivational features, demographics and the three school science/chemistry items were regressed onto motivation change. To allow comparison with other studies, two models were run with only the second containing the three school science/chemistry items. Items in the models and beta values are listed in Table 19. Both models explained about 30% of the variance, which is substantially lower than most other studies (Model 1, $R^{2\ adj.} = 0.309$, $F(8,226) = 14.07$, $p < 0.001$; Model 2, $R^{2\ adj.} = 0.302$, $F(11,223) = 10.21$, $p < 0.001$).

Table 19. *Burning Schools*, all ages: regression onto motivational change

Model		Unstandardised Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.74	2.59		0.29	0.775
	VALUE	2.38	0.65	0.35	3.68	0.000
	SURPRISE-CURIOSITY	1.15	0.47	0.17	2.46	0.015
	PEPK	0.74	0.37	0.13	2.00	0.046
	IMMEDIACY	**0.55**	**0.56**	**0.08**	**0.98**	**0.331**
	Gender	**0.65**	**0.57**	**0.07**	**1.14**	**0.255**
	INTEREST-ENJOYMENT	**0.19**	**0.73**	**0.02**	**0.26**	**0.795**
	Age	-0.42	0.15	-0.17	-2.85	0.005
	PRE-MOTIVATION	-3.47	0.39	-0.58	-8.79	0.000
2	(Constant)	0.63	2.84		0.22	0.824
	VALUE	2.32	0.67	0.34	3.45	0.001
	SURPRISE-CURIOSITY	1.23	0.48	0.18	2.55	0.012
	PEPK	0.73	0.38	0.13	1.95	0.053
	IMMEDIACY	**0.57**	**0.57**	**0.08**	**0.99**	**0.323**
	Gender	**0.68**	**0.58**	**0.07**	**1.17**	**0.245**
	Good-marks	**0.29**	**0.43**	**0.05**	**0.66**	**0.509**
	Science/chemistry*	**0.51**	**0.81**	**0.04**	**0.63**	**0.529**
	INTEREST-ENJOYMENT	**0.26**	**0.76**	**0.03**	**0.34**	**0.738**
	Confident	**-0.15**	**0.46**	**-0.03**	**-0.33**	**0.741**
	Age	-0.45	0.16	-0.18	-2.83	0.005
	PRE-MOTIVATION	-3.56	0.52	-0.60	-6.86	0.000

* Categorical data were coded: studying chemistry = 1, studying general science = 0.

Value, surprise-curiosity, age and pre-motivation all predicted motivation change in both models, while PEPK only significantly predicted motivation change in Model 1 (no school studies items) and had borderline significance (p = 0.053) in Model 2, however its beta value was the same in both. Pre-motivation had the largest effect, approximately twice that of value, and three times that of surprise-curiosity. Pre-motivation had an inverse effect, that is, the greater the motivation prior to the show the less motivation changed. This finding is not surprising; low pre-motivation students have more room to improve, however it may also indicate ceiling effects in measuring

motivation change in high pre-motivation students. None of the three items relating to school studies were significant predictors. In contrast to most other studies, interest-enjoyment did not predict motivation. Immediacy also did not predict motivation, which is different from findings from youth audiences in *Burning Public* who watched essentially the same show, and *QVC* (albeit a younger sample than this study). Consistent with other studies of both mixed age and student samples, age had an inverse effect with older students reporting less motivation change.

Although scale development suggested items tapping surprise and curiosity were operating as a discrete factor and hence, with support from the literature, were made into a composite surprise-curiosity scale, additional regressions (not reported in full) with surprise and curiosity separate were also conducted. In this regression, neither the single-item surprise measure nor the three-item curiosity measure were significant predictors of motivation change. This contrasts with the result for the surprise-curiosity four-item measure, which was a significant predictor.

Motivation change

Watching the show increased motivation, however mean changes were modest. Composite scores for motivation increased significantly from pre ($M = 43.46$, $SD = 11.00$) to post ($M = 44.77$, $SD = 11.15$), $t(264) = -3.68$, $p = 0.000$. Males increased more than females, however the difference was not significant, consistent with the regression results.

Items in the motivation scale were analysed individually, showing that 7 of 13 measures had significantly changed, as seen in Table 20. Full item wordings are listed in Appendix A. Both t-tests and Wilcoxon Signed Rank Tests were used as not all data

was symmetrically normally distributed (an assumption of the t-test, however it is robust to violations). Of the subtle motivational outcomes, students found chemistry significantly less boring (Wilcoxon test only) and more inspiring, however no change was observed in whether they found chemistry fun, interesting or wanted to learn more about it. Several overt motivational outcomes changed significantly, including choosing chemistry in subject choices and at university, and thinking chemistry careers were exciting and wanting to find out more about them. Studying chemistry at university recorded by far the highest change, roughly twice that of most other significant changes, however it also had the lowest pre score. Students also indicated they would be significantly more willing to study chemistry in their spare time, but no change was found in whether they would work hard in school chemistry. No significant change was recorded in two measures regarding general and personal attitudes towards chemistry jobs, however both increased marginally.

In sum, the show appeared to create less change in subtle and more change in overt motivational outcomes. Pre-scores for subtle outcomes were, however, generally higher which may reduce the amount of change. Although changes were small on average, the show was able to positively influence motivation towards studying and careers in chemistry, however not when 'job' was included in item wording.

Table 20. *Burning Schools*: pre, post and change in motivation for each item.

	M (pre)	M (post)	Change	Wilcoxon		t-test	
				Z	p	t	p
Boring*	3.69	3.82	-0.13	-2.12	0.034	-1.94	0.053
Fun	**4.11**	**4.15**	**0.04**	**-0.97**	**0.334**	**-0.91**	**0.362**
Inspiring	3.06	3.25	0.18	-4.28	0.000	-4.52	0.000
Uni	2.91	3.15	0.25	-4.81	0.000	-4.90	0.000
Subject choice	3.12	3.25	0.13	-2.40	0.016	-2.36	0.019
Exciting career	3.33	3.45	0.12	-2.77	0.006	-2.67	0.008
Find careers	3.14	3.25	0.11	-1.99	0.047	-1.98	0.049
Great job	**3.66**	**3.71**	**0.05**	**-0.78**	**0.430**	**-0.92**	**0.357**
Interest	**3.50**	**3.51**	**0.00**	**-0.52**	**0.604**	**-0.37**	**0.711**
Learn more	**3.54**	**3.48**	**-0.05**	**-1.52**	**0.129**	**1.52**	**0.130**
Not job*	**2.98**	**3.06**	**-0.08**	**-1.34**	**0.182**	**-1.12**	**0.265**
Spare time	3.14	3.27	0.13	-2.78	0.005	-2.84	0.005
Work hard	**3.51**	**3.57**	**0.06**	**-1.21**	**0.228**	**-0.95**	**0.344**

Grey indicates non-significant changes.

* Reverse scored items

5.4. Shows with overt motivational outcomes

5.4.1. The Alarming AIDS Adventure (HIV)

This study investigated *The Alarming AIDS Adventure* show at the University of Zululand Science Centre in South Africa's KwaZulu-Natal province. The science centre almost exclusively services urban (township) and rural school groups, as opposed to the general public, with most visitors coming from disadvantaged socioeconomic backgrounds. The centre features hands-on interactive exhibits, science shows, workshops and programs typical of a contemporary science centre, however began adding HIV related initiatives in late 2009. During the period of the present investigation the show formed the major HIV intervention component, however it also included other activities such as games and a career advice session. Further background can be found in section 4.3.6..

Much of the following has been published (Walker et al., 2011), however regression coefficients have been recalculated after including gender data for nine cases where gender had only been recorded in the post-survey (pre-survey gender was used in previous calculations). While data preparation involved comparing demographics between pre- and post-surveys and filling in missing values where appropriate, these nine cases were initially missed. In some cases this recalculation has resulted in beta values slightly different to those published in the paper (e.g. changes from 0.19 to 0.20). In addition, gender's beta value changed from being of borderline significance ($p = 0.056$) to significance ($p = 0.043$), although the actual value remained the same. Apart from the role of gender, these differences do not affect the conclusions reported in the paper.

Sample

The data were collected over seven separate shows over a period of three weeks, with rural and urban students attending separately in most cases. Students attended in the context of a free-of-charge school excursion, with transport arranged and paid for by the science centre.

Table 21. *HIV*: demographics, gender by background and age

		N	Background		Age	
			Rural	Urban	M	SD
Gender	?	9	1	8	14.00	1.41
	F	351	113	238	14.04	1.10
	M	337	127	210	14.61	1.34
Total		697	241	456	14.32	1.26

A sample of 697 students including approximately equivalent numbers of males and females and about twice as many urban compared to rural students were used in the

analysis, as shown in Table 21. Although all attending secondary school, student ages (M = 14.32, SD = 1.36) were quite broad, ranging from 10 to 21.

Scales

Following piloting and item refinement, final pre- and post-show survey instruments were constructed containing 15 HIV-related motivation items. Item wordings are listed in Table 24 (along with individual item changes). Most items directly tapped specific behavioural intentions, representing overt motivational measures. The items represented a wide range of behaviours relevant to HIV derived from the literature and experience with the target audience, with multiple items measuring key facets such as sexual abstinence and condom use, ensuring content validity. Other upstream predictors of motivation and intention such as self-efficacy and attitudes were incorporated, however intention was the focus as it is the endpoint in models and best predictor of behavior, as discussed in section 3.3.. As this study was done extremely early in the PhD project, interest-enjoyment was the only emotional factor investigated. The role of knowledge was a secondary priority, so it was only measured via two items: knowledge of HIV transmission methods (measured pre and post; resulting in a prior knowledge and knowledge change score) and self-reported learning.

Scale scores, as shown in Table 22, were all acceptable. Scores indicated the show was interesting and enjoyable. Knowledge items showed that audiences felt the show was an effective learning experience and there was a significant difference in pre versus post self-reported knowledge of transmission methods, $t(649) = -3.73$, $p = 0.000$.

Table 22. *HIV*: scale and items scores and reliabilities

	N	M	SD	# items	Cronbach's alpha
INTEREST-ENJOYMENT	631	4.06	0.90	4	0.743
Motivation change *	436	2.16	5.57	15	NA
Post-motivation	663	3.88	0.72	15	0.812
Pre-motivation	671	3.72	0.75	15	0.799
Self-reported learning	664	4.08	1.23	1	NA
Transmission (change in knowledge)	646	0.20	1.39	1	NA
Transmission (prior knowledge)	671	3.48	1.28	1	NA

* Motivation change score is the sum of pre to post differences across the 15 scale items, see section 4.7.2..

What influenced motivational change?

A hierarchical linear regression model was used to better understand the factors at play in motivation change. Using total change as the dependent variable, two hierarchical models were tested. Model one included demographic variables (age, gender and rural/urban) and show language as independent variables, while model two additionally included pre-intention score, interest-enjoyment and the three knowledge related items (see Table 23). The aim of the hierarchical model was to test whether gender and rural/urban differences reported in the literature were important when considering motivation change in this context.

Model one (demographics) was not significant and explained negligible variance in motivation change ($R^{2\ Adj.} = 0.016$, $F(4, 403) = 1.65$, non-significant), which was surprising given the differences in demographic groups reported in the literature, as discussed in section 4.3.6.. While the model had essentially no predictive power and was non-significant overall, gender was a significant predictor.

Table 23. *HIV*: regression onto motivational change

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1*	(Constant)	1.71	3.48		0.49	0.624
	Gender	1.42	0.57	0.13	2.50	0.013
	Show language*	**0.17**	**0.70**	**0.02**	**0.24**	**0.808**
	Age	**-0.02**	**0.25**	**-0.01**	**-0.09**	**0.930**
	Rural/Urban*	**-0.10**	**0.76**	**-0.01**	**-0.13**	**0.897**
2	(Constant)	5.34	3.43		1.56	0.120
	INTEREST-ENJOYMENT	3.40	0.32	0.55	10.49	0.000
	Self-reported learning	0.91	0.24	0.20	3.83	0.000
	Transmission (prior knowledge)	0.73	0.25	0.17	2.92	0.004
	Transmission (change in knowledge)	0.50	0.21	0.13	2.34	0.020
	Gender	0.91	0.45	0.08	2.03	0.043
	Show language*	**0.48**	**0.57**	**0.04**	**0.84**	**0.399**
	Age	**-0.03**	**0.20**	**-0.01**	**-0.17**	**0.866**
	Rural/Urban*	**-1.11**	**0.62**	**-0.10**	**-1.79**	**0.074**
	PRE-MOTIVATION	-6.24	0.43	-0.84	-14.64	0.000

* Model F value was non-significant

* Categorical data were coded: rural = 1, urban = 0; isiZulu language = 1, English language = 0

Model two (all predictors) explained 38% of the variance in intention change ($R^{2\ Adj.}$ = 0.383, $F(9,398) = 29.026$, $p<0.001$), a reasonable finding given the relatively simple model (complex intention models predict 39% on average; Armitage & Conner, 2001). Significant predictors were pre-motivation, interest-enjoyment, prior knowledge of transmission methods and self-reported learning at the $p < 0.005$ level, and change in knowledge of transmission methods and gender (male) at the $p < 0.05$ level. Beta coefficients for significant predictors are reported in Table 23. Pre-motivation negatively predicted motivation change, that is, the lower a student's pre-motivation the more motivation increased, and vice-versa. Inspection of standardised beta coefficients showed pre-motivation had the greatest effect on motivation change.

These findings are consistent with the role of pre-motivation in *Burning Schools*. Interest-enjoyment was the next largest predictor, followed by the three knowledge variables, with higher scores associated with greater positive changes in motivation. Interest-enjoyment had a substantially higher beta value compared to other studies, possibly due to the lack of other variables such as value in this study. Finally, being male significantly predicted higher motivation change, however the beta value was the lowest of any variable. In sum, pre-motivation (inverse effect), interest-enjoyment, knowledge related factors, and male gender all predicted motivation.

Motivation change

Overall motivation change was small and positive, reflecting a majority of modest positive changes and some negative changes (M = 2.39, SD = 5.85, n = 437). Males (M = 3.10, SD = 6.62, n = 212) had higher changes than females (M = 1.53, SD = 5.57, n = 222): this gender difference was significant, t(413) = 2.82, p = 0.005. To put this result in context, males also had a significantly lower starting point or pre-motivation score, t(664) = -4.36, p = 0.000. There were no significant differences in intention change between rural (M = 2.48, SD = 6.00, n = 119) and urban (M = 2.34, SD = 6.21, n = 321) students.

As with *Burning Schools*, a non-parametric Wilcoxon Signed Ranks Test and t-tests of the pre- and post-survey scores were used to determine significant changes in motivation for each item. As shown in

Table 24, all items showed modest positive changes (allowing for a reverse scored item), with significant changes in 9 of 15 motivation items including one item of borderline significance (a significant t-test, but non-significant non-parametric tests). In most cases the change represented a strengthening of an already positive

motivation (i.e. agree to strongly agree), as opposed to a complete reversal (i.e. disagree to agree), however the latter did occur in some cases. This points to ceiling effects in survey items, however it may also reflect an already well-intentioned sample or social desirability bias. Despite surveys being anonymous, the effect of wanting to give the 'correct' motivation is likely to have inflated true motivation in this sample, which was subject to different cultural and contextual factors.

Significant changes occurred in motivations measuring resisting peer-pressure, wanting to learn more about HIV, talking to family, and two measures each of sexual abstinence and self-efficacy to behave safely (an upstream influence on motivation and behavioural intention). Condom use and having an HIV test approached but were not significant at the $p < 0.05$ level. Changes to being worried about HIV (vulnerability; another upstream influence), talking to friends, thinking unprotected sex was acceptable, and seeking more HIV information were non-significant. Scores for non-significant items indicated desirable or 'safe' motivations, however they also highlight areas for refinement in the show and survey instrument. On the whole, the show was able to significantly influence a range of HIV related motivations.

Table 24. *HIV*: motivation change across individual items

	M (pre)	M (post)	M change	Wilcoxon		t-test	
				Z	p	t	P
ABC (Abstain, Be faithful, Condomise) is the way I choose to live my life	3.95	4.05	0.10	-1.95	.051	-1.98	.048
At the moment abstinence is the best choice for me	3.57	3.81	0.24	-4.48	.000	-4.50	.000
I am sure I can behave in ways that keep me safe from HIV	3.92	4.14	0.22	-4.18	.000	-4.66	.000
I am worried about catching HIV	**3.60**	**3.62**	**0.02**	**-.41**	**.682**	**-0.50**	**.619**
I plan not to have sex until I am older	3.89	4.08	0.19	-4.03	.000	-3.80	.000
I think I can stay completely safe from HIV AIDS	3.57	3.77	0.20	-3.65	.000	-3.72	.000
I want to learn more about HIV and AIDS	4.01	4.23	0.22	-5.26	.000	-5.14	.000
I will always use a condom, If I do have sex	**4.07**	**4.17**	**0.10**	**-1.79**	**.073**	**-1.95**	**.052**
I will be faithful to one partner, If I do have sex	3.81	4.05	0.24	-4.64	.000	-4.62	.000
I will do ABC (Abstain, Be faithful, Condomise) even if other learners do not do ABC	3.91	4.08	0.17	-3.19	.001	-3.19	.001
I will have an HIV test if I do something unsafe	**3.69**	**3.80**	**0.11**	**-1.87**	**.062**	**-1.85**	**.065**
I will talk about HIV AIDS with my family	3.81	3.99	0.18	-3.45	.001	-3.63	.000
I will talk about HIV AIDS with my friends	**3.70**	**3.75**	**0.05**	**-.96**	**.340**	**-1.01**	**.311**
I will try hard to find new information on HIV AIDS	**3.94**	**3.96**	**0.02**	**-.35**	**.726**	**-0.47**	**.636**
It is OK to have unprotected sex sometimes	**2.26**	**2.25**	**-0.01**	**-.238**	**.812**	**0.19**	**.849**

Non-significant changes are in grey

5.4.2. Sustain-Ability – The Climate Change Show, 2010 (Sustainability 2010)

Sample

This data set was collected during one show of Sustainability – The Climate Change Show performed at the CSIRO Discovery Centre (a science focused venue) during National Science Week. I wrote and performed the show.

Table 25. *Sustainability 2010*: gender by age

		N	Age			
			≤ 18 (youth)	> 18 (adults)	M	SD
Gender	?	2	1	1	22*	NA
	F	30	17	13	25.18	19.14
	M	32	14	18	30.26	21.07
	Total	64	32	32	27.75	20.01

*Based on one case. One case was missing both age and gender.

Audience members were primarily family groups, with Table 25 indicating roughly equivalent numbers of youth and adults, and males and females. Age distribution was typical for family groups (see Figure 9) with large numbers of 7 to 14 year old children and 35 to 50 year old parents. The overall sample size was smaller than most other studies.

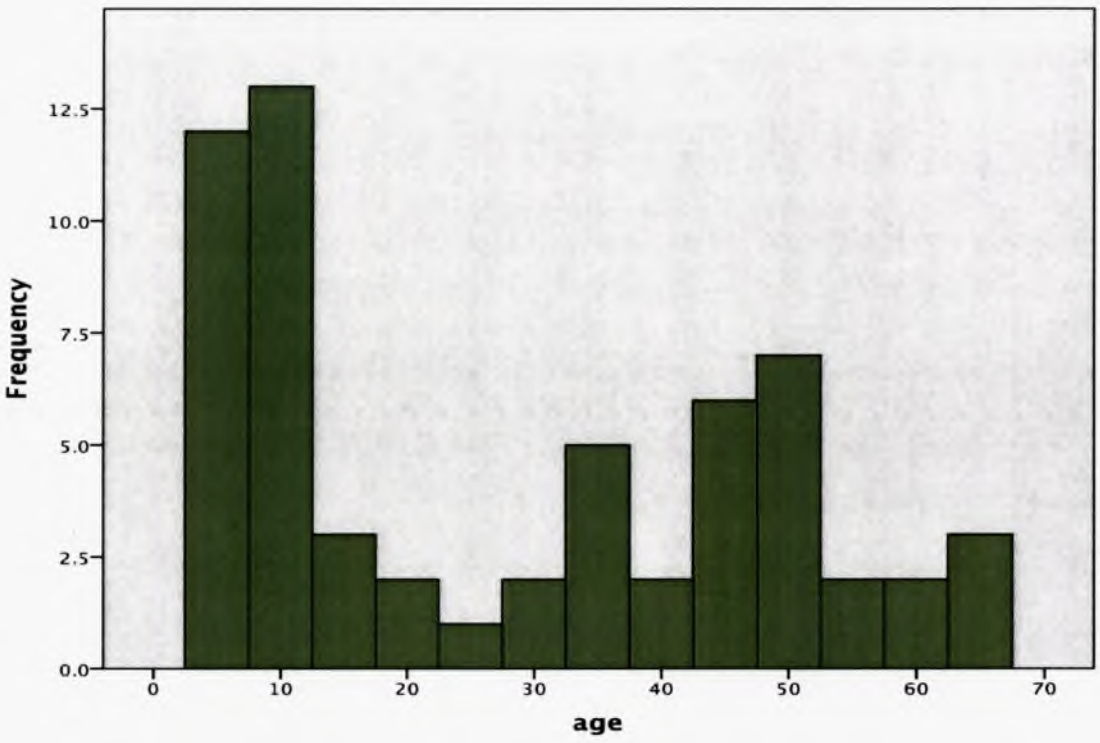

Figure 9. *Sustainability 2010*: age

Scales

After findings from earlier studies, a composite surprise-curiosity scale was initially planned, however factor analysis showed the single item measuring surprise loaded more highly onto the interest-enjoyment factor than the curiosity factor. Various regression models with surprise grouped with curiosity or by itself (where it was not a significant predictor) showed surprise had a negligible role in this study. Hence, to maintain the unidimensionality of the curiosity scale and allow comparison with other studies, the surprise item was dropped.

Table 26. *Sustainability 2010*: scale scores and reliabilities

	N	M	SD	# items	Cronbach's alpha
CURIOSITY	64	3.35	0.94	3	0.725
IMMEDIACY	64	4.29	0.64	7	0.800
INTEREST-ENJOYMENT	64	4.34	0.77	3	0.804
KNOWLEDGE	64	3.77	1.04	2	0.504
MOTIVATION	64	3.68	0.90	7	0.891
VALUE	64	4.13	0.67	6	0.776

Cronbach's alphas for all scales were acceptable, as per Table 26. The lower than desirable knowledge scale was considered acceptable as the scale was diverse (knowledge regarding two different environmental issues), it was a two-item measure, and knowledge is a minor focus of the research.

Mean standardised scale scores followed a similar pattern to other studies with results for interest-enjoyment and immediacy above 4 and between 3 and 4 for other variables. Value, however, recorded a higher mean compared to other studies reflecting that the audience found the show more relevant to the real world and personally valuable. This is consistent with the main focus of the show being how people can help address climate change.

What influenced motivational outcomes?

Provisional regression analyses showed weak heterogeneity of residuals and anomalous results, so a log transformation was applied to motivational outcomes. A two-stage hierarchical model, first with motivational features, second adding demographics, was regressed on transformed motivational outcomes. The hierarchical model was chosen as provisional analyses had suggested that age and knowledge were related. Model one explained 52% of the variance in motivational outcomes, $R^{2\ adj.} = 0.520$, $F(5,53) = 13.58$, $p < 0.001$. Beta coefficients in Table 27 show value was the strongest predictor, and along with knowledge significantly predicted motivation. Model two explained about 6% more variance or 58%, $R^{2\ adj.} = 0.576$, $F(7,51) = 12.25$, $p < 0.001$. The addition of age and gender resulted in knowledge no longer being a predictor; instead age now significantly inversely predicted motivation (as with other studies), while the effects of value remained largely unchanged. Gender did not predict motivational outcomes.

Table 27. *Sustainability 2010*: regression onto log motivational outcomes

Model		Unstandardised Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.06	0.07		0.92	0.361
	VALUE	0.06	0.02	0.41	3.19	0.002
	KNOWLEDGE	0.03	0.01	0.26	2.57	0.013
	CURIOSITY	0.01	0.01	0.12	1.19	0.241
	INTEREST-ENJOYMENT	0.02	0.02	0.12	0.83	0.412
	IMMEDIACY	0.01	0.02	0.04	0.31	0.761
2	(Constant)	0.09	0.07		1.31	0.198
	VALUE	0.07	0.02	0.44	3.57	0.001
	CURIOSITY	0.02	0.01	0.19	1.86	0.069
	KNOWLEDGE	0.02	0.01	0.16	1.58	0.120
	IMMEDIACY	0.02	0.02	0.14	0.99	0.327
	INTEREST-ENJOYMENT	0.00	0.02	0.03	0.20	0.844
	Gender	0.00	0.02	0.02	0.26	0.794
	Age	0.00	0.00	-0.28	-2.99	0.004

As this study used post-only motivation measures, an item 'I'm already doing everything I can to help the environment' (already-doing) was included to assess whether people were already motivated and doing the target behaviours. As motivation items were worded to capture change from the show, high scores for already-doing could explain low motivation scores. Mean scores for already-doing indicated audience members were neutral (M = 3.23, SD = 1.41). While already-doing did not significantly predict motivation when other variables were included, when regressed alone it was a significant positive predictor ($B^{std.}$ = 0.351, p = 0.004) and accounted for 11% of the variance in motivation ($R^{2\ adj.}$ = 0.109, F(1,62) = , p < 0.005). If this item functioned as intended, however, one may expect an inverse relationship; people already doing pro-environmental behaviours would experience less change. Instead, the data here suggests that people who are already engaging in pro-environmental behaviours are more likely to make more changes too – also a logical outcome.

5.4.3. Sustain-Ability – The Climate Change Show, 2011 (Sustainability 2011)

Sample

The data presented here were from two performances of *Sustain-Ability! – The Climate Change Show* performed at Questacon – The Australian National Science and Technology Centre. Audience members were mainly patrons who were visiting Questacon anyway, with a small proportion of people coming especially for the show. The show was offered free-of-charge, which is different from Questacon's usual arrangements.

Table 28. *Sustainability 2011*: gender by age

		N	Age			
			≤ 18 (youth)	> 18 (adults)	M	SD
Gender	?	3	2	1	23.67	22.86
	F	101	59	42	23.87	15.71
	M	69	28	41	28.75	18.03
Total		173	89	84	25.82	16.85

Most people attended in family groups, with children aged around 10 and parents aged around 40 making up the bulk of the group. Age data are shown in Table 28 and distribution in Figure 10. Youth and adults were approximately equally divided. Almost twice as many female youth attended compared to male youth due to a class from a girl's school on an interstate excursion, while gender was approximately equally split in adults.

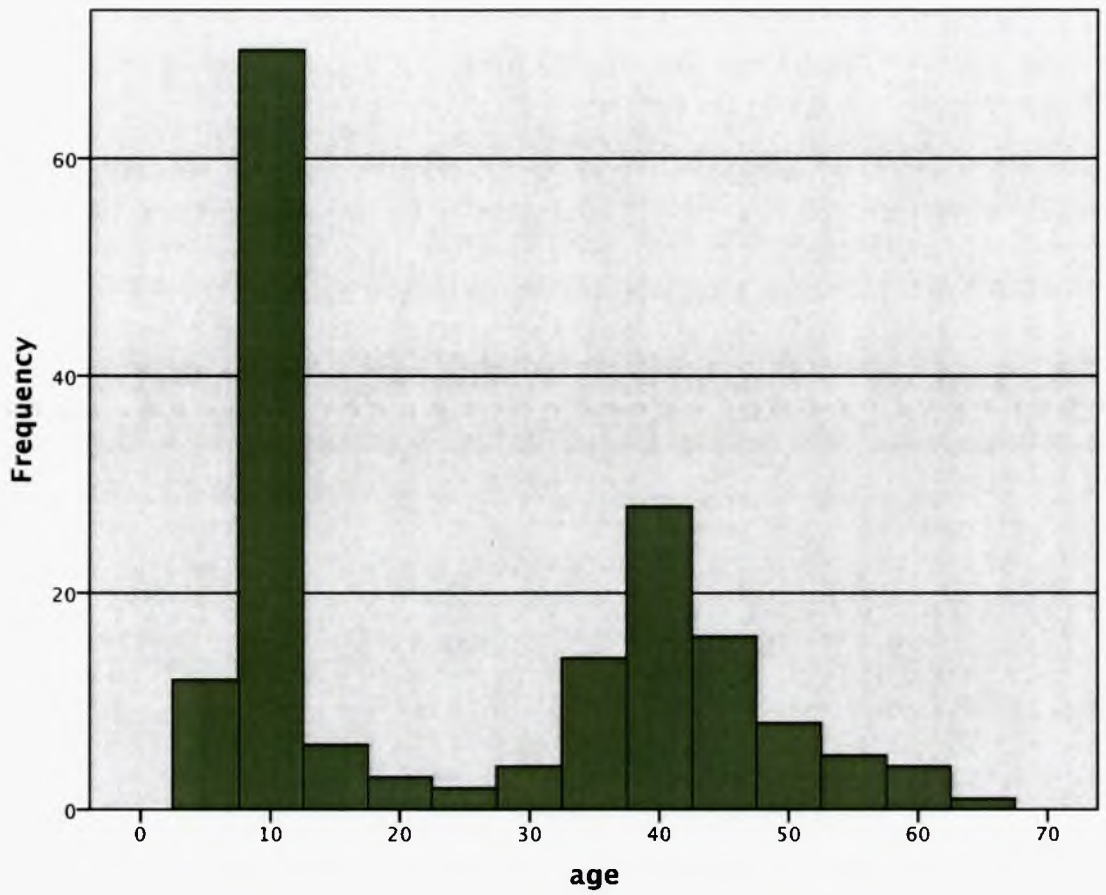

Figure 10. *Sustainability 2011*: age

Scales

Table 29. *Sustainability 2011*: scale scores and reliabilities

		N	M	SD	# items	Cronbach's alpha
Other	IMMEDIACY	90	4.32	0.55	4	0.761
	KNOWLEDGE CHANGE *	80	1.08	2.46	5	NA
	MOTIVATION CHANGE *	76	3.47	4.36	7	NA
	POST-KNOWLEDGE	88	4.32	0.56	5	0.827
	POST-MOTIVATION	88	4.00	0.68	7	0.871
	PRE-KNOWLEDGE	165	4.05	0.60	5	0.639
	PRE-MOTIVATION	161	3.49	0.75	7	0.799
	VALUE	88	4.05	0.67	4	0.838
DES+	CURIOSITY	141	3.71	0.75	3	0.780
	ENJOYMENT	146	4.06	0.66	3	0.784
	INTEREST	143	3.82	0.72	3	0.743
	SURPRISE	143	3.71	0.87	3	0.846

* Change score is the sum of pre to post differences across all items in the scale, see section 4.7.2. for calculation procedure.

Cronbach's alphas indicated that scale reliabilities were acceptable, as shown in Table 29. The pre-knowledge scale was somewhat lower than ideal, but not too low to be discounted given the breadth of items. The rise in reliability of the post-knowledge scale indicates that knowledge became more consistent pre to post. Although using fewer items than previous studies, immediacy and value scales had good reliability. Items for these scales were selected based on being conceptually representative and performing reliably in previous studies, so it is reassuring to see they performed consistently with this different audience and show.

The DES scales were effective, yielding high reliabilities and discrete factor structure with minimal co-loading while being straightforward, simple to answer and easy to accommodate on the survey. The three-item curiosity scale which was added to the DES gave similar reliability to the tested DES items.

The results show a large difference in N for different scales, which was due to the sequencing and page layout of the surveys – unfortunately many audience members did not complete the second page of the post-survey. This resulted in pre-measures Ns in the 160s, post-measure Ns of emotions in the 140s, and post-measure Ns for motivation and motivational variables in the 80s.

What influenced motivational change?

In other regression analyses, outliers outside three standard deviations were excluded, including new outliers created as initial outlying cases were removed. The small N of this data set meant if that procedure was followed, a large proportion of cases were removed which caused the model to be over- or even perfectly-fitted with extremely high values for R square. Inspection of residual plots showed a model including

outliers, while not the standard approach, actually provided the best fit for the data set as a whole. Removing even the two most extreme outliers resulted in a model that inaccurately predicted motivation change, especially for higher values. Hence outliers were included in regression analyses in this study.

Table 30. *Sustainability 2011*: regression onto motivation change

Model		Unstandardised Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	-6.18	3.23		-1.91	0.060
	ENJOYMENT	**2.20**	**1.15**	**0.34**	**1.92**	**0.060**
	CURIOSITY	**0.84**	**1.03**	**0.14**	**0.82**	**0.415**
	SURPRISE	**0.15**	**0.86**	**0.03**	**0.18**	**0.858**
	INTEREST	**-0.78**	**1.04**	**-0.13**	**-0.75**	**0.454**
2	(Constant)	-3.81	2.53		-1.51	0.137
	VALUE	3.01	0.61	0.46	4.94	0.000
	PRE-KNOWLEDGE	2.48	0.60	0.34	4.16	0.000
	KNOWLEDGE CHANGE	0.57	0.15	0.32	3.86	0.000
	IMMEDIACY	**0.63**	**0.61**	**0.08**	**1.03**	**0.305**
	ENJOYMENT	**0.46**	**0.65**	**0.07**	**0.71**	**0.480**
	Gender	**0.06**	**0.52**	**0.01**	**0.12**	**0.904**
	SURPRISE	**0.02**	**0.44**	**0.00**	**0.04**	**0.967**
	CURIOSITY	**-0.33**	**0.57**	**-0.06**	**-0.57**	**0.571**
	INTEREST	**-0.53**	**0.53**	**-0.09**	**-1.01**	**0.319**
	Age	-0.07	0.02	-0.27	-4.28	0.000
	PRE-MOTIVATION	-4.33	0.39	-0.74	-11.13	0.000

All variables were regressed onto motivation change using a two-stage hierarchical model, which first added emotions and curiosity, and second all other variables and demographics. Beta values and significant predictors are shown in Table 30. Model one predicted only 10% of the variance, $R^{2\ adj.} = 0.095$, $F(4,67) = 2.86$, $p = 0.030$. None of the emotions or curiosity significantly predicted motivation change, with enjoyment the only variable approaching significance. Model two had much stronger predictive power, explaining 78% of variance in motivation change, $R^{2\ adj.} = 0.779$, $F(11,60) = 23.69$, $p < 0.001$. The R Square value was particularly high compared to other studies.

Pre-motivation had by far the largest effect, almost twice that of other variables, and was inversely related to motivation change. That is, the higher pre-motivation was, the less change occurred, which is consistent with other pre-post studies. Value was the next largest significant predictor, followed by knowledge-change, pre-knowledge and age (inverse relationship). None of the emotions or curiosity (as with model one), nor immediacy or gender were significant predictors. In sum, pre-motivation, value, knowledge and age all predicted motivation change.

Motivation and knowledge change

The show increased scores for both motivation and knowledge. Mean scale scores showed a significant increase of 3.47 in motivation from pre (M = 24.20, SD = 5.21) to post (M = 27.67, SD = 4.85); t(79) = -6.94, p = 0.000. Changes in knowledge were smaller yet still significant, t(79) = -3.91, p = 0.000, rising 1.08 from pre (M = 20.36, SD = 2.58) to post (M = 21.44, SD = 2.8). Consistent with regression results, gender had no effect on change of either knowledge or motivation. Age, on the other hand, did play a role. Compared to adults, youth scored significantly lower in pre-motivation, t(153) = -2.27, p = 0.025, and also reported significantly more motivation change, t(72) = 3.43, p = 0.001. This is consistent with the idea that those low in pre-motivation experience the most change, as suggested in the regression.

Individual item scores all increased, with significant changes in six-of-seven motivation and two-of-five knowledge items, as shown in Table 31 and Table 32 respectively. People's motivation to engage in specific behaviours including composting, recycling, using ethanol blended petrol and using renewable energy all significantly increased. Putting more effort into helping the environment and talking to friends about actions that can help also increased significantly, however there was no significant increase in

people's willingness to encourage pro-environmental behaviour in others. People's knowledge of the environmental benefits of ethanol, and understanding of why certain actions affect climate change significantly increased. Knowledge regarding the benefits of recycling, renewable energy and the impact of individual actions did not significantly increase, but pre-scores (M = 4.21) indicated knowledge was already high in these areas. In sum, the show had positive effects on both knowledge and motivation, with significant increases in scale scores and about two-thirds of individual items.

Table 31. *Sustainability 2011*: motivation change

	M (pre)	M (post)	Mean change	Wilcoxon		t-test	
				Z	P	t	p
Compost	3.43	3.96	0.53	-4.51	0.000	-4.95	0.000
Encourage others	**3.80**	**3.93**	**0.13**	**-1.23**	**0.219**	**-1.24**	**0.218**
Ethanol	3.08	3.86	0.78	-6.33	0.000	-8.66	0.000
Renewable energy	3.02	3.91	0.89	-5.62	0.000	-6.90	0.000
More effort	3.80	4.15	0.35	-3.01	0.003	-3.23	0.002
Recycle	4.00	4.31	0.31	-2.25	0.024	-2.27	0.026
Talk to friends	3.30	3.89	0.59	-4.30	0.000	-4.79	0.000

Table 32. *Sustainability 2011*: knowledge change

	M (pre)	M (post)	Mean change	Wilcoxon		t-test	
				Z	P	t	P
Ethanol benefits	3.55	4.12	0.57	-4.47	0.000	-5.15	0.000
Individual actions	**4.20**	**4.40**	**0.20**	**-0.48**	**0.631**	**-0.46**	**0.650**
Recycling benefits	**4.22**	**4.46**	**0.24**	**-0.61**	**0.540**	**-0.61**	**0.544**
Renewables	**4.21**	**4.32**	**0.11**	**-0.45**	**0.651**	**-0.45**	**0.657**
Understand effects	3.99	4.36	0.37	-3.52	0.000	-3.80	0.000

5.5. Summary: What features of a science show are motivational?

This chapter addressed the central research question of how the identified motivational features were associated with motivational outcomes from a science show. The following section summarises results of regression analyses presented throughout the chapter. This highlights a number of trends within the data as a whole.

First I will look at how much variance in motivation can be explained by the variables investigated. Following that, beta values for emotions and motivational variables, and then the effects of demographic factors, will be compared across studies.

Table 33. Adjusted R Square values for regression onto motivational outcomes or change, all studies

	$R2^{adj.}$
Post-only studies	
Booming	0.309
QVC	0.588
Ballistics	0.570
Burning Public, all ages	0.492
Burning Public, youth	0.554
Burning Public, adults	0.480
Sustainability 2010	0.576
M	0.530
SD	0.054
Pre-post studies	
Sustainability 2011	0.779
HIV	0.383
Burning Schools	0.309
M	0.490
SD	0.253
Overall M	0.518
Overall SD	0.129

As listed in Table 33, R Square values for post-only studies explained 45% to 68% of variance in motivation. In general, post-only studies investigated similar independent variables in relation to subtle motivational outcomes. In contrast, the range was broader for pre-post studies investigating change in overt motivation, explaining 31% to 78% of variance. In comparing the three pre-post studies, note *Sustainability 2011*'s comparatively high figure of 78% is inflated due to the small sample size with less overall variance (motivation change had the lowest standard deviation of all studies), along with relationships between value and the subject matter, as discussed in the next chapter. The other two pre-post studies, *HIV* and *Burning Schools*, had the lowest

R Square values. In addition, these studies were student samples and not free-choice settings. Models using student samples with overt outcomes explained of a mean of 35% of variance, compared to 42% in all student samples (adding *QVC*), and 56% in non-student free-choice settings. In studies with overt outcomes and people not attending freely, the independent variables investigated had less power to explain overt motivational outcomes.

5.5.1. Role of the identified motivational features

The significance and magnitude of standardised beta values provides a way to compare the *relative* effects of the motivational features on motivation across studies. Standardised beta values and their significance for emotions, motivational variables and other factors (i.e. knowledge) are listed in Table 34 and also shown in Figure 11. Mean beta values are calculated on all studies where the variable was measured, regardless of whether the predictor was significant or not.

Pre-post designs are most powerful as they isolate motivation change – the actual impact the show is having, rather than just an end point. These clearly show pre-motivation (beta M = -0.72) was the largest predictor of motivation change. Pre-motivation had an inverse relationship with motivation change in all pre-post studies; the lower the initial motivation, the more motivation increases, and vice-versa. Pre-motivation is, however, not a factor that can be influenced by the show or presenter (aside from selection of the audience).

Table 34. All studies: standardised beta values for predictors of motivational outcomes or change

	Motivational features / other variables									
	Interest-enjoyment	Surprise	Curiosity	Immediacy	Knowledge	Knowledge change	PEPK	Pre-motivation	Realworld	Value
Post-only studies										
Booming	0.14	0.21 *	0.21 *	0.17						0.32
QVC	0.15	0.21	0.12	0.33					0.16	
Ballistics	0.18 *	0.26	0.29	0.14					0.09	
Burning Public, all ages	0.17	0.12	0.07	0.07			-0.16			0.54
Burning Public, youth	0.24	0.09	-0.07	0.19			-0.07			0.53
Burning Public, adults	0.07	0.06	0.23	0.05			-0.10			0.50
Sustainability 2010	0.03		0.19	0.14	0.16					0.44
Pre-post studies										
Sustainability 2011	-0.01	0.00	-0.06	0.08	0.34	0.32		-0.74		0.46
HIV	0.55				0.17	0.13 *		-0.84		
Burning Schools	0.02	0.17 *	0.17 *	0.08			0.13 *	-0.58		0.35
M	0.16	0.14	0.13	0.14	0.22	0.23	-0.05	-0.72	0.13	0.45
SD	0.16	0.09	0.13	0.09	0.10	0.14	0.13	0.13	0.05	0.08

Blank cells indicate variable was not measured during study. *Sustainability 2011* interest-enjoyment score is an average of interest and enjoyment scores that were measured separately.

* Significant at $p \leq 0.05$. Grey shading: non-significant predictor. All other figures significant at $p \leq 0.005$.

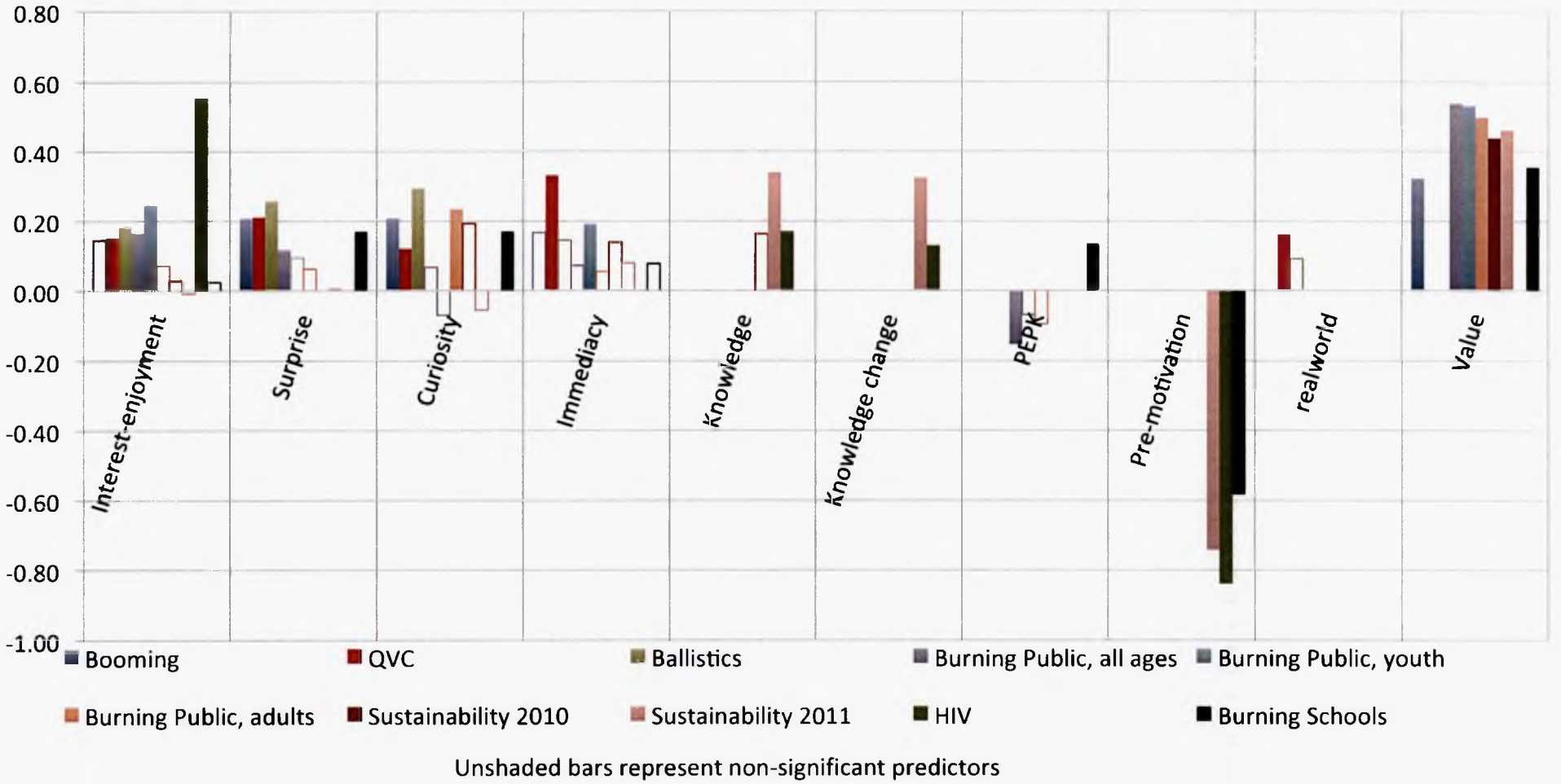

Figure 11. All studies: beta values for predictors of motivational outcomes or change.

When considering post-only as well as pre-post designs, value was clearly the next largest predictor. In all but one study, value (M = 0.45) had the largest effect after pre-motivation. Higher reports of value were associated with higher motivation. Moreover, although heavily reliant on audience characteristics, value is an aspect that can be manipulated via show content and presentation.

Knowledge and knowledge change had the next largest magnitude beta values (M = 0.22 and 0.23 respectively) after value, however – in line with the focus of this research – these variables were only measured in two studies. In addition, mean beta values for knowledge were significantly increased by high scores in *Sustainability 2011*, in which knowledge beta values were two to three times that of other studies. *Sustainability 2011* used conceptually related knowledge and motivation items (e.g. both about recycling) that may increase knowledge beta values. These high values may be due to this conceptual link, rather than a general knowledge-motivation link.

Interest-enjoyment (the emotional component of SI) was the next most influential variable. Beta values for interest-enjoyment (M = 0.16) show it was a significant predictor of motivation in five of ten studies. Interest-enjoyment beta values were higher in youth audiences, a trend best shown through its high significant value in *Burning Public* youth, lower significant value in *Burning Public* all ages, and lower still and non-significance in *Burning Public* adults. A second trend apparent is that interest-enjoyment was not significant in any studies with overt motivational outcomes, except *HIV* where other influential variables (e.g. value) were not measured, which will increase the effect of interest-enjoyment (indeed, its beta value in *HIV* was two to three times that of other studies).

Surprise (M = 0.14) and curiosity (M = 0.13) had the next largest and approximately equivalent effects on motivational outcomes, with significance in five of eight and five of nine studies respectively. Composite surprise-curiosity measures, as supported by factor analysis, in two studies would have caused means to converge. The strongest trend evident was that surprise and curiosity beta values were highest in shows I presented (*Booming* and *Ballistics*), where show content and presentation was designed to increase these responses through the use of discrepant events. Surprise and curiosity's effect on subtle and overt outcomes is less clear. In general, surprise and curiosity had effects on subtle outcomes depending on the presenter (comparing *Booming* and *Ballistics* with *Burning Public*) and also had effects on a mixture of subtle and overt outcomes (*Burning Schools*), however had no significant effect on purely overt outcomes (*Sustainability 2010* and *2011* – note these shows did not use discrepant events).

PEPK was significant in two of four studies. Beta values indicate a negative relationship in three studies and positive relationship in one study, meaning mean beta value is not a representative statistic. Beta values were negative in *Burning Public*, where it was only significant in the all ages sample, and positive in *Burning Schools*, where it was also significant. This inverse effect of PEPK when different audiences watched the same show will be explored in the next chapter. Its inclusion in only four studies makes any wider trends difficult to identify.

Immediacy (M = 0.14) was only significant in two of nine studies, however its mean value was the same as surprise and curiosity. Both studies where immediacy was a significant predictor (*QVC* and *Burning Public* youth) had youth audiences and subtle outcomes, and moreover immediacy did not predict motivation in adult audiences or

with overt outcomes. The relatively high value for immediacy in *QVC* may have been inflated by the absence of value in that study.

5.5.2. Role of demographics: age and gender

Demographic variables, in particular age, predicted motivation in numerous studies. Standardised beta values are listed in Table 35 and shown in Figure 12. Age (M = -0.16) significantly predicted motivational outcomes in eight of ten studies. Age had a consistent inverse relationship, with older ages reporting lower motivation. This trend was evident in mixed age audiences and youth audiences, but not adult audiences. Age's effects were not clearly influenced by the type of motivational outcomes, however the highest beta values did occur in overt outcome studies (*Sustainability 2010* and *2011*).

Table 35. All studies: age and gender standardised beta values when predicting motivational outcomes or change

	Age	Gender
Post-only studies		
Booming	-0.27	0.17 *
QVC	-0.06 *	**0.02**
Ballistics	-0.16 *	**0.09**
Burning Public, all ages	-0.13	0.09 *
Burning Public, youth	-0.23	0.16 *
Burning Public, adults	**-0.03**	**0.03**
Sustainability 2010	-0.28	**0.02**
Pre-post studies		
Sustainability 2011	-0.27	**0.01**
HIV	**-0.01**	0.08 *
Burning Schools	-0.17	**0.07**
M	-0.16	0.07
SD	0.10	0.06

* Significant at $p \leq 0.05$. Grey shading: non-significant predator. All other figures significant at $p \leq 0.005$.

Gender's effects (M = 0.07) were more sporadic, however the four of ten studies where it was a significant predictor all show being male was associated with greater

motivational outcomes. No entirely consistent trends are evident, however three of the four shows (*Booming* and *Burning Public* all ages and youth) were presented by males and involved fire and explosions – content that might be anecdotally more associated with males.

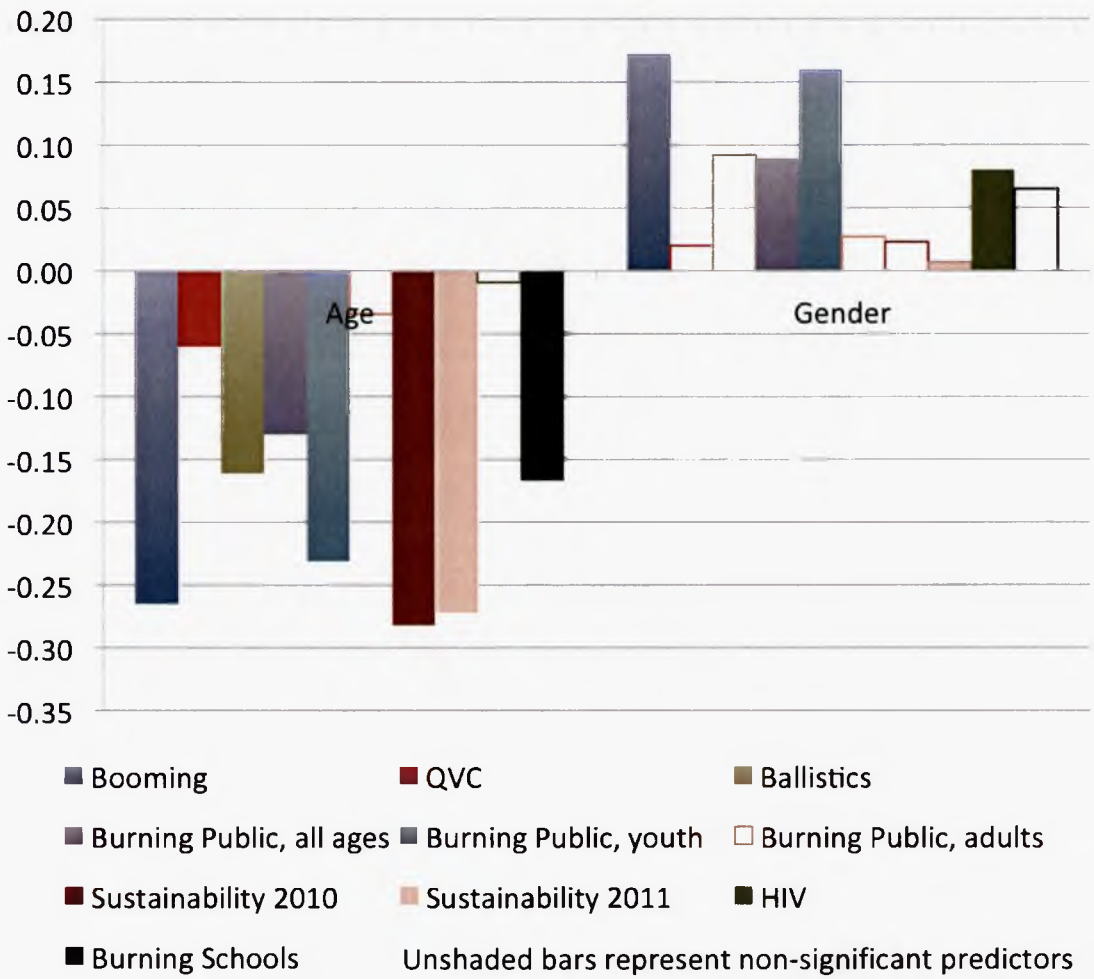

Figure 12. All studies: age and gender standardised beta values when predicting motivational outcomes or change.

This concludes results related to the main research questions that look at the relationship of motivation with motivational features and demographics. I will now turn to results regarding relationships between the identified motivational features, as raised in the sub-questions.

5.6. Sub-questions

The following sections present results relevant to the sub-questions that emerged from the literature review (see section 3.4.1.). The sub-questions essentially look at relationships between motivational features (the independent variables discussed in previous results). Correlation, factor and regression analyses are used to elucidate these relationships, as discussed in section 4.7.3.. For clarity, this section is arranged by these analyses as some relate to more than one sub-question, with results summarised in relation to the sub-questions after each analysis and brought together in section 5.6.4..

5.6.1. Correlation between motivational features

As shown in Table 36, most motivational features were significantly correlated with each other (note 'significantly' will not be repeated each time below). Exceptions included curiosity and interest-enjoyment which were not correlated with PEPK, while surprise and interest-enjoyment were not correlated with age. Several observations relate to the sub-questions. (1) PEPK was negatively correlated with surprise ($r = -0.29$, $p < 0.001$), not correlated with curiosity ($r = 0.07$, non-significant), and positively correlated with value ($r = 0.40$, $p < 0.001$). (2) Surprise's correlation was highest with curiosity ($r = 0.40$, $p < 0.001$), lower with interest-enjoyment ($r = 0.27$, $p < 0.001$), and lower still with value ($r = 0.20$, $p < 0.05$; these latter two are SI components). (3) Immediacy and interest-enjoyment had the highest correlation ($r = 0.53$, $p < 0.001$) of any variables; immediacy and value also had a higher correlation ($r = 0.48$, $p < 0.001$) than most other variables, and (4) Interest-enjoyment and curiosity were correlated ($r = 0.28$, $p < 0.001$), however the magnitude was midrange in relation to all significant correlations.

Table 36. *Burning Public* all ages: correlations between emotions, motivational variables and age.

	PEPK	CURIOSITY	SURPRISE	INTEREST-ENJOYMENT	IMMEDIACY	VALUE	Age
PEPK	1.000	0.069	-0.293	0.090	0.173	0.400	0.171
CURIOSITY			0.398	0.280	0.321	0.408	0.155
SURPRISE				0.267	0.250	0.118*	-0.048
INTEREST-ENJOYMENT					0.529	0.419	-0.026
IMMEDIACY						0.476	.165
VALUE							.121*
Age							

Non-significant correlations are in grey. * $p < 0.05$. All other correlations $p < 0.005$.

N range from 380 to 419 due to missing values

Table 37. *Burning Public* all ages: correlations between interest-enjoyment and immediacy items, and between immediacy items.

	Immediacy items					
	Funny	Humour	Enthusiastic	Liked presenter	Interaction	Feel part
Interest-enjoyment items						
Fun	0.246	0.217	0.322	0.298	0.313	0.253
Interesting	0.243	0.257	0.325	0.405	0.278	0.261
Enjoyed	0.250	0.246	0.243	0.373	0.251	0.254
Immediacy items						
Funny		0.413	0.251	0.224	0.241	0.260
Humour			0.212	0.322	0.240	0.368
Enthusiastic				0.402	0.204	0.266
Liked presenter					0.259	0.298
Interaction						0.426
Feel part						

All correlations $p < 0.001$

N range from 409 to 424 due to missing values

A second correlation analysis was conducted between individual items in immediacy and interest-enjoyment, as the literature and analyses reported below suggest they may be related. Moreover, the literature suggests that different aspects of immediacy might have different effects on motivation. All immediacy and interest-enjoyment items were significantly correlated. Overall, correlations between the interest-enjoyment items and the two immediacy items regarding the presenter (likeability and enthusiasm) were higher than others. Within the immediacy items, three conceptually related couplets were evident – funny-humour, enthusiastic-liked presenter and interaction-feeling part of the show – which each had higher correlations above 0.4.

5.6.2. Factor analysis

Three factor analyses of the *Burning Public* data set were conducted: (1) all items (part of the scale development process), (2) items of all motivational features, and (3) items measuring surprise, interest-enjoyment, curiosity and PEPK (two iterations). Results

reported below primarily focus on aspects relating to the sub-questions. Full item wordings can be found in Appendix A.

As shown in Table 38, an interpretable six-factor structure emerged following Oblimin rotation. The six-factor solution explained 58% of the variance. Factors, from one to six, were value, surprise/PEPK, interest-enjoyment (plus two immediacy items), curiosity, motivation and immediacy.

Although the factor structure was much as the theory would predict, several aspects were noteworthy. Co-loading occurred between one item in the surprise/PEPK factor measuring prior experience and the value factor. In the surprise/PEPK factor, loadings were negative for surprise, unexpectedness and schema-discrepancy ('different to thought') items and positive for PEPK items, showing an inverse relationship. Two immediacy items relating to the presenter – their enthusiasm and likeability – formed a factor with the three interest-enjoyment items, however this did not occur in the motivational features only analysis presented next.

The curiosity item formed a factor with two items tapping D-curiosity's underlying aspects of deprivation/information-gaps, which asked if people were still wondering or still had questions about the show. The general public associated curiosity with a search for missing information. This D-curiosity factor was independent of interest-enjoyment, with no salient co-loading (above 0.3). In general, the motivational features formed neat independent factors with the exception of PEPK and surprise, interest-enjoyment and immediacy, and to a smaller extent value and PEPK.

Table 38. *Burning Public*: factor analysis of all items

	1	2	3	4	5	6
Personal interest	0.726					
Useful	0.546					
Important	0.540					
Relevant	0.517					
Everyday life	0.443					
Surprised		- 0.688				
Unexpected		- 0.654				
Already knew (PK)		0.598				
Different to thought		- 0.494				
Seen/done before (PE)	0.329	0.379				
Enjoyed			0.793			
Interesting			0.731			
Fun			0.567			
Liked presenter			0.387			
Enthusiastic			0.356			
Still questions				0.766		
Still wondering				0.713		
Curious				0.416		
More interested					0.776	
More excited					0.727	
More positive					0.650	
Discover more	0.388				0.476	
Inspired	0.358				0.459	
Feel part of the show						0.500
Humour						0.495
Funny						0.461
Outside world						0.456
Interaction						0.378
Initial eigenvalues	7.356	2.808	2.008	1.747	1.297	1.082

Principal Axis Factoring extraction, Oblimin rotation. Loadings below 0.3 are omitted.

Factors: 1. Value, 2. Surprise/PEPK, 3. Interest-enjoyment (presenter immediacy), 4. Curiosity, 5. Motivation, 6. Immediacy.

As described further in Appendix A, three items in the motivation scale were discarded as they showed co-loading which had a conceptual basis – i.e. between motivation to seek information and curiosity – as discussed in the Methods, section 4.7.2.. The two items which co-loaded with the value factor, as shown in Table 38, were retained as loadings were of low magnitude, there was minimal or no conceptual basis linking

them to value, and they improved the motivation scale's reliability (although it is acknowledged this co-loading is not ideal).

The second factor analysis omitted the motivation items to draw out more detail of the relationships between the motivational features. Reducing the number of variables essentially 'sharpens the focus' on relationships between the variables that remain. Factors, from one to five, were immediacy, surprise/PEPK, D-curiosity, value, and interest-enjoyment, as shown in Table 39. The five factors explained 56% of the variance.

Several important changes occurred in the factor structure. With regards to the surprise/PEPK and D-curiosity factors, the item measuring schema-discrepancy ('different to thought') instead factored out with the D-curiosity items, however also co-loaded onto the surprise/PEPK factor. Unexpectedness remained with the surprise/PEPK factor, but in this analysis also co-loaded on the D-curiosity factor. Factor loadings indicate schema-discrepancy had a similar association with surprise/PEPK and D-curiosity factors, while unexpectedness was more associated with surprise/PEPK. Neither surprise nor D-curiosity showed any relation to interest-enjoyment or value (components of SI). Co-loading of the prior experience item onto value (found in the previous analysis) was not present. The same two presenter-related immediacy items remained as part of the interest-enjoyment factor, however this time also co-loaded with similar magnitude on the immediacy factor.

In sum, the motivational features only analysis was consistent and built on the previous all items version – surprise and PEPK remained related, additional evidence for the interest-enjoyment and immediacy relationship was present, and D-curiosity and interest-enjoyment remained independent. This analysis, however, also showed a

relationship between surprise/PEPK and D-curiosity – which were primarily linked through schema-discrepancy – and ruled out value-PEPK associations previously found.

Table 39. *Burning Public*: factor analysis of motivational features only.

	1	2	3	4	5
Feel part of the show	0.616				
Humour	0.551				
Funny	0.511				
Interaction	0.466				
Outside world	0.405	- 0.301			
Already knew (PK)		- 0.734			
Surprised		0.618			
Unexpected		0.498	0.357		
Seen/done before (PE)		- 0.493			
Still questions			0.763		
Still wondering			0.668		
Curious			0.440		
Different to thought		0.332	0.391		
Personal interest				- 0.716	
Important				- 0.631	
Relevant				- 0.557	
Useful				- 0.500	
Everyday life				- 0.499	
Enjoyed					0.793
Interesting					0.711
Fun					0.554
Liked presenter	0.305				0.357
Enthusiastic	0.308				0.336
Initial Eigenvalues	5.822	2.718	1.845	1.364	1.120

Principal Axis Factoring extraction, Oblimin rotation. Loadings below 0.3 are omitted.
Factors: 1. Immediacy, 2. Surprise/PEPK, 3. D-curiosity, 4. Value, 5. Interest-enjoyment

Unreported factor analysis iterations showed this relationship between surprise/PEPK and D-curiosity, linked mainly via schema-discrepancy and to a lesser extent via unexpectedness items, remained when the value and immediacy items were removed. Not until PEPK was removed did the structure change.

Table 40. *Burning Public*: factor analysis of surprise, curiosity and interest-enjoyment items.

	1	2	3
Unexpected	0.866		
Different to thought	0.667		
Surprised	0.624		
Enjoyed		0.845	
Interesting		0.686	
Fun		0.656	
Still questions			0.798
Still wondering			0.738
Curious		0.302	0.359
Initial Eigenvalues	3.281	1.619	1.195

Principal Axis Factoring extraction, Oblimin rotation. Loadings below 0.3 are omitted. Factors: 1. Surprise, 2. Interest-enjoyment, 3. D-curiosity.

Table 40 shows factor analysis for surprise (factor 1), interest-enjoyment (2) and curiosity (3) items only. The three factors explained 68% of the variance. The major change from the previous analysis was, without the PEPK items included, schema-discrepancy moved back to the surprise factor (in line with the literature) and there was no co-loading between the surprise and curiosity factors. Co-loading did occur with the curiosity item, which loaded both onto the D-curiosity and interest-enjoyment factors. In sum, while previous analyses had shown a surprise/PEPK and D-curiosity relationship, when PEPK was removed surprise and curiosity formed discrete factors.

Given the previous analyses had shown PEPK, surprise and curiosity were intimately related, a final factor analysis was conducted with these variables. Table 41 shows a two-factor solution, with surprise and curiosity combined in factor one, PEPK in factor two, and co-loading of two surprise items. The two factors explained 57% of the variance. The structure suggests surprise and curiosity are extremely closely related – they form a single factor – however almost all other variables have to be removed

before this will happen. It also shows that while surprise and PEPK are related, as shown by the co-loading, curiosity and PEPK are not related.

Table 41. *Burning Public*: factor analysis of surprise, curiosity and PEPK items.

	1	2
Still wondering	0.666	
Still questions	0.643	
Curious	0.584	
Unexpected	0.539	-0.419
Different to thought	0.527	
Surprised	0.518	-0.439
Already knew		0.737
Seen/done before		0.569
Initial Eigenvalues	2.850	1.742

Principal Axis Factoring extraction, Oblimin rotation. Loadings below 0.3 are omitted. Factors: 1. Surprise/D-curiosity, 2. PEPK

Taken together, findings from the factor analyses showed relationships between: (1) surprise and PEPK; (2) interest-enjoyment and immediacy (via qualities of the presenter); and (3) surprise/PEPK and D-curiosity (via schema-discrepancy). They also showed independence between: (1) surprise and interest-enjoyment or value (SI components); (2) interest-enjoyment and D-curiosity; and (3) D-curiosity and PEPK. Evidence exists for a very close relationship between surprise and curiosity, but they are distinct constructs.

5.6.3. Regression analyses: which motivational features predict each other?

The following sections report regression results using the different emotions and motivational variables as both dependent and independent variables. As with the main analysis of motivational outcomes, R Square values indicate the proportion of variance explained by the motivational features, while beta values show which motivational

features are most strongly associated with each other. Each regression was done in two stages, first including motivational features, then adding age and gender.

Curiosity

The motivational features explained 29% of variance in curiosity, and 30% when age and gender were added ($R^{2\ Adj.}$ = 0.299, F(7,372) = 24.07, p<0.001). As shown in Table 42, value and surprise predicted curiosity with similar beta values. Age positively predicted curiosity – being older was associated with greater curiosity – but with a beta value approximately half that of other significant predictors. PEPK and interest-enjoyment did not predict curiosity, consistent with factor analysis results that showed their independence.

Table 42. *Burning Public*: regression onto curiosity

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.67	0.41		1.60	0.109
	SURPRISE	0.35	0.05	0.35	7.12	0.000
	VALUE	0.39	0.07	0.31	5.72	0.000
	IMMEDIACY	**0.13**	**0.10**	**0.07**	**1.29**	**0.197**
	PEPK	**0.03**	**0.05**	**0.03**	**0.62**	**0.538**
	INTEREST-ENJOYMENT	**0.02**	**0.09**	**0.02**	**0.28**	**0.781**
2	(Constant)	-0.29	0.41		-0.72	0.943
	SURPRISE	0.35	0.05	0.35	7.15	0.000
	VALUE	0.39	0.07	0.31	5.70	0.000
	Age	0.01	0.00	0.13	2.81	0.005
	INTEREST-ENJOYMENT	**0.07**	**0.09**	**0.04**	**0.75**	**0.451**
	IMMEDIACY	**0.07**	**0.10**	**0.04**	**0.66**	**0.508**
	PEPK	**0.02**	**0.05**	**0.02**	**0.34**	**0.734**
	Gender	**-0.05**	**0.07**	**-0.03**	**-0.72**	**0.474**

Surprise

All motivational features except value predicted surprise. The motivational features explained 35% of variance, which remained steady with age and gender added ($R^{2\ Adj.}$ = 0.354, F(7,365) = 30.09, p<0.001). Surprise's largest predictor was curiosity (see Table 43), with a positive relationship between the two. PEPK, in contrast, had a negative relationship; the beta value magnitude indicates it predicted surprise to the same degree as curiosity but with an inverse relationship. Interest-enjoyment and immediacy also significantly predicted surprise, with equivalent beta values that were about half that of curiosity. Surprise was not predicted by age or gender.

Table 43. *Burning Public*: regression onto surprise

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.29	0.36		3.59	0.000
	CURIOSITY	0.33	0.04	0.35	7.45	0.000
	INTEREST-ENJOYMENT	0.25	0.08	0.16	3.16	0.002
	IMMEDIACY	0.27	0.09	0.16	3.05	0.002
	VALUE	**0.03**	**0.07**	**0.03**	**0.52**	**0.602**
	PEPK	-0.29	0.04	-0.35	-7.73	0.000
2	(Constant)	1.38	0.36		3.81	0.000
	CURIOSITY	0.33	0.05	0.35	7.43	0.000
	INTEREST-ENJOYMENT	0.25	0.08	0.16	3.13	0.002
	IMMEDIACY	0.26	0.09	0.16	2.89	0.004
	VALUE	**0.04**	**0.07**	**0.03**	**0.61**	**0.543**
	Age	**0.00**	**0.00**	**-0.06**	**-1.27**	**0.204**
	Gender	**-0.11**	**0.07**	**-0.07**	**-1.64**	**0.103**
	PEPK	-0.28	0.04	-0.34	-7.37	0.000

Interest-enjoyment

The motivational features explained 32% of variance in interest-enjoyment and increased to 34% with age and gender included ($R^{2\ Adj.} = 0.338$, $F(7,367) = 28.27$, $p<0.001$). In order of beta value magnitude shown in Table 44, immediacy, value, gender and surprise predicted interest-enjoyment. Immediacy's beta value was three- to four-fold that of the other predictors. Male gender predicted higher interest-enjoyment (positive beta value). Age was of borderline significance, with beta values indicating an inverse relationship. Curiosity and PEPK did not predict interest-enjoyment.

Table 44. *Burning Public*: regression onto interest-enjoyment

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.16	0.20		10.58	0.000
	IMMEDIACY	0.41	0.05	0.42	8.38	0.000
	VALUE	0.13	0.04	0.18	3.35	0.001
	SURPRISE	0.07	0.03	0.12	2.41	0.017
	CURIOSITY	**0.01**	**0.03**	**0.02**	**0.47**	**0.639**
	PEPK	**-0.03**	**0.03**	**-0.06**	**-1.13**	**0.261**
2	(Constant)	2.02	0.21		9.85	0.000
	IMMEDIACY	0.44	0.05	0.45	8.99	0.000
	VALUE	0.12	0.04	0.17	3.08	0.002
	Gender	0.12	0.04	0.13	3.06	0.002
	SURPRISE	0.07	0.03	0.12	2.40	0.017
	CURIOSITY	**0.03**	**0.03**	**0.04**	**0.88**	**0.379**
	PEPK	**-0.03**	**0.02**	**-0.05**	**-1.06**	**0.291**
	Age	0.00	0.00	-0.09	-1.96	0.051

Immediacy

Interest-enjoyment, value and surprise, along with both age and male gender (inverse relationship) predicted immediacy, as shown in Table 45. The motivational features predicted 39% of variance, or 42% with age and gender added ($R^{2\ Adj.} = 0.420$, $F(7,369) = 39.93$, $p<0.001$). Interest-enjoyment had by far the largest beta value, followed by value, gender, age and surprise. Gender had an inverse relationship with immediacy; being male predicted lower levels of immediacy. This was the opposite of gender's relationship to interest-enjoyment, which according to the factor analysis is closely related to immediacy. Curiosity and PEPK were not predictors.

Table 45. *Burning Public*: regression onto immediacy

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.61	0.19		8.41	0.000
	INTEREST-ENJOYMENT	0.36	0.04	0.40	8.69	0.000
	VALUE	0.17	0.04	0.24	4.66	0.000
	SURPRISE	0.07	0.03	0.12	2.48	0.014
	CURIOSITY	**0.03**	**0.03**	**0.06**	**1.21**	**0.228**
	PEPK	**0.02**	**0.02**	**0.05**	**0.95**	**0.345**
2	(Constant)	1.60	0.19		8.55	0.000
	INTEREST-ENJOYMENT	0.39	0.04	0.43	9.49	0.000
	VALUE	0.16	0.04	0.24	4.73	0.000
	Age	0.00	0.00	0.12	2.83	0.005
	SURPRISE	0.06	0.03	0.11	2.33	0.021
	CURIOSITY	**0.02**	**0.03**	**0.03**	**0.58**	**0.560**
	PEPK	**0.02**	**0.02**	**0.03**	**0.72**	**0.474**
	Gender	-0.14	0.04	-0.16	-3.88	0.000

Value

43% of value's variance was explained by the other motivational features and unaffected by age and gender ($R^{2\ Adj.}$ = 0.431, F(7,370) = 41.84, p<0.001). PEPK, curiosity, immediacy and interest-enjoyment (in order of beta value) all positively predicted value – see Table 46. Surprise, age and gender did not predict value.

Table 46. *Burning Public*: regression onto value

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-0.40	0.28		-1.40	0.162
	PEPK	0.22	0.03	0.31	7.33	0.000
	CURIOSITY	0.22	0.04	0.28	6.25	0.000
	IMMEDIACY	0.34	0.07	0.24	5.04	0.000
	INTEREST-ENJOYMENT	0.26	0.06	0.20	4.22	0.000
	SURPRISE	**-0.02**	**0.04**	**-0.02**	**-0.51**	**0.610**
2	(Constant)	-0.426	0.29		-1.48	0.139
	PEPK	0.22	0.03	0.31	7.27	0.000
	CURIOSITY	0.22	0.04	0.28	6.26	0.000
	IMMEDIACY	0.35	0.07	0.25	5.12	0.000
	INTEREST-ENJOYMENT	0.24	0.06	0.19	3.90	0.000
	Gender	**0.05**	**0.05**	**0.04**	**0.91**	**0.365**
	Age	**0.00**	**0.00**	**-0.02**	**-0.45**	**0.651**
	SURPRISE	**-0.02**	**0.04**	**-0.02**	**-0.47**	**0.636**

PEPK

31% of variance in PEPK was explained by the motivational features and was not increased by adding age and gender ($R^{2\ Adj.} = 0.309$, $F(7,368) = 29.99$, $p<0.001$). As shown in Table 47, surprise negatively predicted PEPK, whereas value positively predicted PEPK (consistent with the reciprocal analyses). All other variables did not predict PEPK.

Table 47. *Burning Public*: regression onto PEPK

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.59	0.42		6.18	0.000
	VALUE	0.61	0.07	0.45	8.41	0.000
	IMMEDIACY	0.17	0.11	0.09	1.62	0.107
	CURIOSITY	0.00	-0.06	0.00	-0.05	0.963
	INTEREST-ENJOYMENT	-0.05	0.10	-0.03	-0.53	0.597
	SURPRISE	-0.41	0.05	-0.37	-7.61	0.000
2	(Constant)	2.49	0.43		5.85	0.000
	VALUE	0.60	0.07	0.44	8.29	0.000
	IMMEDIACY	0.15	0.11	0.08	1.38	0.169
	Age	0.00	0.00	0.08	1.81	0.072
	Gender	0.06	0.08	0.03	0.70	0.483
	CURIOSITY	-0.02	0.06	-0.01	-0.28	0.781
	INTEREST-ENJOYMENT	-0.04	0.10	-0.02	-0.37	0.714
	SURPRISE	-0.39	0.05	-0.35	-7.24	0.000

Regression analyses – summary

Table 48 shows beta values and significance for regression of the motivational features on each other. With regards to the sub-questions, predictor relationships in the regression findings included: (1) immediacy and interest-enjoyment (large beta value), and immediacy and value; (2) surprise with PEPK (inverse relationship) and curiosity; and (3) PEPK and value. In contrast with the factor analysis results, regression showed that surprise was not independent of interest-enjoyment (SI component), however beta values show a much stronger relationship between surprise and curiosity (beta = 0.35) than surprise and interest-enjoyment (beta = 0.12). Results also showed no significant relationship (did not predict each other) between: (1) interest-enjoyment and curiosity; (2) surprise and value (SI component); and (3) curiosity and PEPK.

R Square values showed the motivational features were somewhat interrelated and explained from 29% to 43% of variance in each other, with age and gender having a negligible effect on variance explained. Both value and surprise were more interrelated than the other variables; every motivational feature except each other predicted them.

Table 48. *Burning Public*: standardised beta values for predictors of motivational features.

Predictors	Dependent variable					
	CURIOSITY	IMMEDIACY	INTEREST-ENJOYMENT	PEPK	SURPRISE	VALUE
Age	0.13	0.12	-0.09	0.08	-0.06	-0.02
Gender	-0.03	-0.16	0.13	0.03	-0.07	0.04
CURIOSITY		0.03	0.04	-0.01	0.35	0.28
IMMEDIACY	0.04		0.45	0.08	0.16	0.25
INTEREST-ENJOYMENT	0.04	0.43		-0.02	0.16	0.19
PEPK	0.02	0.03	-0.05		-0.34	0.31
SURPRISE	0.35	0.11*	0.12*	-0.35		-0.02
VALUE	0.31	0.24	0.17	0.44	0.03	

Non-significant predictors are in grey. * $p < 0.05$. All other significant predictors $p < 0.005$.

5.6.4. Results relevant to the sub-questions

The following section provides a summary of results that relate to each sub-question. Discussion and answers to the sub-questions are covered in section 6.7..

1) Is the I/D-curiosity distinction valid during a learning experience like a science show?

Several results suggested that the two dimensions of curiosity – I- and D-type – proposed by Litman and colleagues (2004, 2008) were operating during a science show. As discussed, I-curiosity is similar to what is referred to here as interest-enjoyment. Note, however, that I-curiosity refers specifically to interest and enjoyment when finding out information, whereas the interest-enjoyment measures here were more general. Correlations between D-curiosity and interest-enjoyment ($r = 0.28$) were significant but compared to all correlated items were mid-range in magnitude, showing mild association between the two. In contrast, regression findings showed no association: curiosity did not predict interest-enjoyment, or vice-versa.

Factor analysis primarily showed that interest-enjoyment items and D-curiosity items were distinct – there was typically no co-loading. When all other variables except surprise were removed, however, there was co-loading for the item that measured curiosity. It loaded more highly onto the D-curiosity factor than the interest-enjoyment factor – where the loading was only just salient (0.302). In all factor analyses, the curiosity item factored out with the two items describing information-gaps and deprivation, which indicated the audience associated the term 'curiosity' with D-curiosity conceptualisations and perceive it as distinct from interest.

2) Is surprise linked to D-curiosity, SI or both?

Results indicated a stronger relationship between surprise and D-curiosity compared to surprise and interest-enjoyment (SI component), and surprise was unrelated to value (SI component). Correlations were higher for surprise and curiosity ($r = 0.40$) compared to interest-enjoyment ($r = 0.26$) and value ($r = 0.12$). Factor analysis showed no association between surprise and interest-enjoyment or value (SI components). There was, however, a close association between surprise and D-curiosity, which co-loading shows were linked through PEPK and schema-discrepancy. When all other variables except PEPK were removed, factor analysis showed surprise and curiosity items formed a single factor indicating a very close relationship. Surprise predicted both D-curiosity and interest-enjoyment, with beta values about three times higher for D-curiosity. Surprise did not predict value.

3) Are the theorised links between PEPK and surprise, PEPK and curiosity and PEPK and value reflected empirically?

Taken together, results supported an inverse relationship between PEPK and surprise, independence between PEPK and curiosity, and a positive relationship between PEPK and value. PEPK was negatively correlated with surprise, not correlated with curiosity, and positively correlated with value. Factor analyses showed that although surprise and curiosity were very closely associated, PEPK was only associated with surprise. PEPK and value formed discrete factors. Regression showed PEPK negatively predicted surprise, did not predict curiosity, and positively predicted value.

4) Is immediacy a motivational variable in its own right, or are its effects mediated via another motivational variable or emotion(s) as suggested in the literature?

All three analyses showed a strong relationship between immediacy and interest-enjoyment. Correlations between the two were the highest of any measured (0.529), moreover correlations between the individual items, particularly those measuring presenter likeability and enthusiasm, were all significant. Factor analysis showed immediacy and interest-enjoyment were connected primarily via presenter likeability and enthusiasm, which sometimes co-loaded or factored out with interest-enjoyment items. Immediacy predicted interest-enjoyment in regression analysis, with large beta values suggesting a strong relationship. Correlation and regression results also indicated a relationship, albeit weaker, between immediacy and value – the other component of SI studied.

The next chapter discusses these results and answers the research sub-questions in section 6.7., however begins with discussion of the main research questions: were the shows motivational and what was the role of the identified motivational features?

Chapter 6. Discussion: What features of a science show motivate people?

6.1. Overview

This chapter discusses results presented in Chapter 5 which address the central research question in this thesis: What features of a science show motivate people? To answer this question, it was first necessary to identify which motivational features are most relevant to a science show context, which were reviewed in Chapters 2 and 3. This review identified the emotions of interest, enjoyment and surprise, along with the motivational variables of curiosity, immediacy and value (denoted 'motivational features'). In addition, knowledge (as a component of SI) and PEPK were identified as secondary variables of importance. Chapter 4 outlined how these motivational features can be measured via scales, which were then used in regression models to see which variables predicted motivational outcomes or change and to determine their relative strength. Chapter 4 also outlined the two types of research designs used: post-only and pre-post measurements, the second of which produces a motivation change score. The results from using these methods across 10 samples (eight shows, one of which was divided into three subsamples) were presented in Chapter 5.

As stated in earlier chapters, the main research question can be broken down into two parts: (1) do science shows motivate people, and if so, (2) are the identified motivational features associated with motivation? This chapter is arranged as outlined in Figure 13. First, show settings and characteristics of the samples are reviewed to place the results in context. Second, to establish if shows motivate people, motivational outcomes or change generated by the shows are discussed, in particular

those studies which investigated overt motivational outcomes using more robust pre-post designs (*HIV*, *Burning Schools* and *Sustainability 2011*). Third, the critical question of what role the identified motivational features play in influencing these outcomes is addressed. Fourth, the relationships of motivational outcomes to the motivational features and demographic variables are discussed. Fifth, the research sub-questions are discussed, focusing on relationships between motivational features. These interrelationships are then put in the broader context of overall motivation.

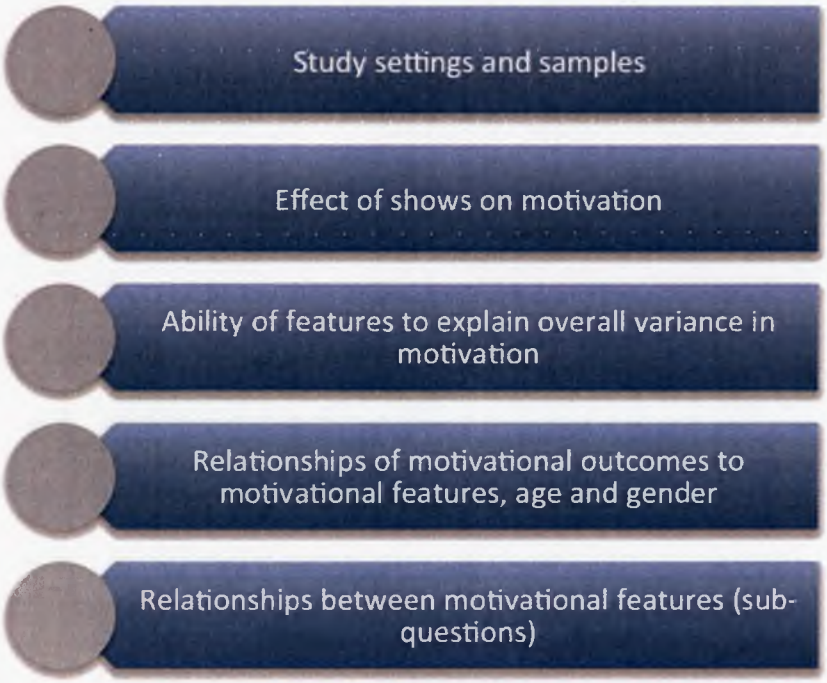

Figure 13. Overview of chapter structure.

At times, I will make brief mention of practical outcomes, recommendations, limitations, and the relation of findings to other research, however these aspects will be dealt with in more detail in Chapter 7.

6.2. Context: show settings and sample characteristics

The contexts studied here were predominantly free-choice settings. Although it is impossible to be sure, it can be assumed that audiences attended primarily for

intrinsically motivated reasons and, as with most ISL experiences, outcomes from the show are also intrinsically motivated to some degree (as argued in section 2.2.1. and 2.2.2.). Apart from *QVC*, *Burning Schools* and *HIV*, which were organised school incursions/excursions, people attended of their own free will. This means it is likely the bulk of the sample had a positive view of science, ISL experiences, or informal learning settings generally. In short, they are already engaged with science. As most people attended in family groups, one can reasonably assume that both the decision-making adults and the youth who supported that decision by wanting to come hold these positive views. Hence, apart from the three school shows, this sample represents the science-engaged; they are likely to be more motivated about science than the general public, and certainly more than the science-disengaged. What motivates outcomes in this group that freely attend may therefore be different from what motivates other groups.

R Square values (see section 5.5.), which were substantially lower in school settings (not free-choice), support this view. Low R Square values in school samples suggest that other unmeasured variables played a greater role in facilitating motivation in these groups, and that the variables studied – mainly intrinsic motivators – had less influence on motivational outcomes (this point is discussed in detail in section 6.4.1.). Moreover, all shows studied were conducted in venues such as science centres and universities, and promoted through their networks under their banners, which is also likely to have attracted a science-engaged sample. This bias in the sample that attended public shows – that when given free-choices they choose 'science' – needs to be remembered as results are interpreted. School settings, on the other hand, are not

free-choice. Although students may prefer a science show to standard classes, they still do not represent an entirely free-choice setting.

Most of the sample studied in this thesis fits into two groups: families or school students. Most of the free-choice public shows were attended by groups of adults and younger children (termed 'families' whether related or not). Observations and age distributions suggest most families had young children aged 5-14 accompanied by parents or guardians aged 35-55. The 15-30 year old group of teens and young adults was underrepresented in most public shows, showing that in free-choice decisions they are not choosing science shows, even when they are cost free. The exception to this was *Burning Public*, which attracted numerous 18-30 year olds, most likely university students. This was probably due to the university venue, promotion via its channels (especially chemistry) and the chemistry focused explosions and fire theme.

Gender was equally balanced in almost all shows, showing that in general males and females are both equally attracted to science shows. Differences were, however, recorded in two shows. More males attended *Ballistics* and *Burning Public* – both shows involving fire and explosions. Male youth made up most of the imbalance, whereas significantly more male adults attended *Burning Public* and significantly fewer attended *Ballistics* (even though one show was a Fathers Day event). Consistent with the stereotype, it appears male youth do indeed like burning and blowing things up. School samples comprised primary school (*QVC*) or secondary school (*Burning Schools* and *HIV*) age students and approximately equal numbers of males and females. The school samples included a broad range of cultural backgrounds, rural/regional/urban dwellers, and socioeconomic backgrounds (private and public schools, and the seriously disadvantaged).

In summary, the samples studied in school shows represented a wide range of students in a non free-choice environment, whereas the samples from public shows represented families in free-choice environments who are most likely already science-engaged. Underrepresented are 15-30 year olds almost across the board, and young females in those shows that focused on explosions and fire. These underrepresented groups should be earmarked for greater engagement through science shows and other ISL experiences.

6.3. Do science shows motivate people? Motivational outcomes and change

As noted in the literature review, the question of whether ISL settings like science shows motivate people is only beginning to be explored. Results from studies here suggest that the answer, in the short-term at least, is yes. In the pre-post studies, which most robustly address this question by measuring motivation change, all three studies recorded significant increases in overall motivation. Motivation was measured with a range of items ensuring content validity. Moreover, the three pre-post studies focused on overt motivational measures: most items measured motivational dispositions to concrete and specific cases of intended behaviour such as condom use, university study or recycling. These overall changes, while significant, were small in magnitude ranging from approximately 1.3 (*Burning Schools*) up to 3.5 (*Sustainability 2011*). To put this in perspective, a change of 1.0 represents a net change of one scale unit on a Likert scale (e.g. 'agree' to 'strongly agree') across all the scale items. Standardised pre- and post-motivation scale scores (a score out of five that can be compared to Likert results) show that, on average, changes represented a shift from neutral to positive motivations (pre-motivation$^{std.}$ M = 3.52); meaning in general

people were moving from 'neutral' to 'agree'. The data thus show that science shows can significantly increase motivation, albeit to a modest degree.

In all three pre-post studies a majority of individual motivation items significantly increased. About half increased in *Burning Schools* (7 of 13), two-thirds in *HIV* (9 of 15) and almost all in *Sustainability 2011* (6 of 7). All items that did not significantly increase indicated stable neutral to desirable motivations ('neutral' to 'agree' on a Likert scale). This could indicate an already positively motivated audience that is hence less likely to change, ceiling-effects in the instrument, that the show was not motivational in these aspects – or a combination of all three. Importantly, individual items describing motivation and behaviour that were central to the show's aims often showed the greatest change. For example, the highest increases in *Burning Schools* were for studying chemistry at university, in *Sustainability 2011* they were for using green energy and ethanol blended petrol, and in *HIV* they were for sexual abstinence and single-partner relationships. In the first case this was a desired but not explicitly pushed aim, while in the two other cases these were key aims of the shows and heavily promoted. This outcome demonstrates that science shows can increase motivation generally and, moreover, effectively deliver targeted motivational messages.

These findings are consistent with research reviewed in section 3.3., although they add to the evidence presented there in several ways. First, the three pre-post studies add considerably to quantitative evidence that shows can have a motivational impact, as until now only one external study has used pre- and post-measurements of motivation and attitude change from science shows (Caleon & Subramaniam, 2007). The data presented in this thesis does not, however, shed any light on the persistence of

attitude and motivation change, which Caleon and Subramaniam found was not present after two weeks (this limitation will be discussed further in section 7.5.). Second, the studies in this thesis show that science shows alone are able to influence overt motivational outcomes. While previous research has established that museum and science centre visits – usually focusing on the impact of exhibitions – can have positive effects on health related intentions (Carney et al., 2009; Cartmill & Day, 1997), the *HIV* study presented here demonstrates that science shows can also facilitate such change. Moreover, the two *Sustainability* studies provide quantitative evidence that ISL experiences and, in particular, science shows can influence pro-environmental attitudes and intentions. This data build on the predominantly qualitative research that has previously addressed this issue, none of which has looked at science shows.

Motivation change in individual shows

In *Burning Schools*, 7 of 13 motivation items significantly increased. These included several overt motivational outcomes, including choosing chemistry in school and university subject choices, along with several related subtle outcomes including thinking chemistry careers were exciting and wanting to find out more about them. These results are consistent with other research investigating chemistry shows discussed in section 3.3.. As noted, studying chemistry at university recorded by far the highest change, roughly twice that of most other significant changes. While further chemistry study was mentioned in passing during the show, it was not prominently promoted. It is possible that the subtle approach taken – 'implying' rather than directly 'telling' students that chemistry study and careers are fun and worthwhile – is more effective for teenage/secondary school students (something anecdotal experience suggests). Given that many ISL projects aim to motivate science careers and further

study, the question of how such motivational messages are best framed is an important subject for future research. The university chemistry lecture theatre setting may also have influenced the comparatively high increase in motivation for university study. Students also indicated they would be significantly more willing to study chemistry in their spare time, which is testament to the show's motivational effect. The selective chemistry presented (exciting explosions and bright coloured flames), may however, influence responses to items like this.

In contrast, while careers and study motivations increased, no change was recorded in two items regarding general and personal attitudes towards chemistry jobs. Similarly, while willingness to study chemistry in spare time increased, no change was found in whether respondents would work hard in school chemistry. Measurement ceiling effects are an unlikely explanation for no change being recorded, with pre-measures of about 3-3.5 in these items. So, while the show changed shorter-term overt outcomes such as university study, free-choice chemistry learning and subtler attitudinal type measures (e.g. feelings towards careers), it did not influence motivation towards longer-term concrete outcomes, especially when using the term 'job' which implies work, and non-free-choice learning. As noted earlier, the show did not aim to blatantly promote chemistry jobs or encourage effort in chemistry at school, so these findings should not be viewed as a failing of the show. The contrasting results may, however, be linked to the underlying nature of the science show context. That is, the overall pattern of change fits with the context in which chemistry is presented during the show: it is fun, not work. Hence, the show affected things perceived as fun (doing chemistry in one's spare time) but not something perceived as work (school chemistry study).

Turning to *HIV*, change was more widespread with significant increases in 9 of 15 items. These spanned both overt behavioural intention measures and conceptually related subtler attitudinal measures. Given the potentially life-saving messages in this show, this is an encouraging result for the impacts a science show can have. The show significantly increased responses relating to resisting peer-pressure, free-choice HIV learning, talking to family, and two measures each of sexual abstinence and self-efficacy to behave safely (an upstream influence on motivation).

Several items, however, remained unchanged. Items measuring motivation to use condoms and seek more information about HIV may have been subject to ceiling effects, with pre-scores of approximately 4. Further efforts to increase concreteness and specificity of items, which also makes them better predictors of actual behavior (Ajzen, 1989; Cartmill & Day, 1997), may help address ceiling effects. Tailoring items more specifically to the sample (culture, real-life situations, gender, etc.), employing 7-point scales, and crafting items to minimise the effect of socially acceptable answers are other potential solutions (Walker et al., 2011). No change in an item asking if it is all right to have unprotected sex sometimes (M^{pre} = 2.25) highlights the pitfalls of less concrete items. For example, students may have thought of examples where someone may intend to fall pregnant. Nevertheless, the score for this item indicates a 'safe' attitude. Average scores of approximately 3.7 for motivation to have an HIV test following risky behavior, and talking to friends about HIV, indicate areas for show refinement, especially given the significant increase in talking to family.

Scores for being worried about catching HIV remained unchanged at approximately 3.6, which indicate wariness without outright fear. Participants may have also reported lower worry due to their intentions to behave safely represented in other items. Given

that the show aimed not to overplay the fear message, this result is reassuring. Discussions with a well-informed Zulu science center staff member who suggested the use of confronting images of AIDS patients, however, suggest that fear could be a powerful motivator. This view challenges the argument for a focus on positive emotions presented in section 2.4.5., however a raft of ethical issues need to be considered before negative emotions are deliberately aroused by science shows, especially dealing with an issue like HIV AIDS. Nevertheless, one could argue for the use of emotions like fear if they result in positive motivational effects. Future research to address this should, however, be very carefully considered.

Sustainability 2011 had the biggest effect on motivation both by magnitude of change and proportion of items affected (6 of 7). Trends are more elusive due to this widespread impact, although two explanations are possible for items that experienced different amounts of change. On the one hand, items with the highest mean change scores were associated with more novel and exciting demonstrations. Using ethanol blended fuel ($M^{change} = 0.78$) and renewable energy ($M^{change} = 0.89$) featured demonstrations involving dramatic ignition of ethanol in a 15L water dispenser bottle, children racing solar powered cars with large 'sun' lamps, and a volunteer blowing on a model wind turbine connected to a electricity meter. These are unique and unusual experiences. In comparison, recycling ($M^{change} = 0.31$) and composting ($M^{change} = 0.53$) were both featured in one straightforward demonstration involving a 'recycling race' where volunteers try to set a record time recycling into different bins – something common in households.

On the other hand, the amount of change recorded in each item corresponds with item pre-scores. Higher pre-scores were associated with less change and vice-versa.

This pattern also emerged at the scale level in all regression analyses, shown by high negative beta values for pre-motivation. This suggests the most likely explanation is that items with low pre-motivation scores undergo greater change due to the low starting point. Moreover, changes in knowledge variables fit the pre-motivation explanation, but only partially fit the novel demonstration explanation. It is probable both explanations play a role, however the evidence points more strongly to the pre-motivation hypothesis. That said, we know little about how different demonstration types influence motivation or other outcomes, however Sadler's (2004) research on this subject suggests it is a worthwhile area for future study.

The high motivation and knowledge change in *Sustainability 2011* needs to be qualified. Results may have been influenced by the smaller sample size (N = 173) and low completion of motivation items on the second page of the survey (motivation change scores could only be calculated for 76 participants). Moreover, those that did complete all items may be more likely to have had a positive show experience and hence experience more change. Nevertheless, the show was still effective in motivating people across a range of pro-environmental behaviours.

Post-only studies give a less robust indication of motivation from the shows, but because items were worded to capture change or indicate subsequent behaviour, they are still relevant. Post-motivation scores across the five post-only studies (M = 3.79, SD = 0.28) show that audiences tended to consistently agree that the show had been motivational. Subtle outcomes dominated these motivational scales, suggesting the show positively affects dispositions toward science and intentions to seek more information and think more about the shows. Scales for *Sustainability 2010* and one

item in *QVC* also measured some overt outcomes, which returned similar scores to the subtle measures.

In sum, data from the post-only studies support the conclusion from the pre-post studies: science shows increase motivation. This finding is consistent across different topics, show presenters, types of motivational outcomes, free-choice public shows and non free-choice school show, and diverse audiences (age, culture and geographic location). Motivation significantly increased in both composite scale measures and a majority of individual items, demonstrating shows are a motivational experience overall and effective at delivering specific motivational messages. Moreover, shows were able to increase motivation in traditional applications such as influencing career aspirations, as well as innovative areas such addressing environmental and health issues. These studies, however, only assessed motivation change immediately after the show and make no claims on whether it is sustained. I now move to discussion of how the motivational features were associated with such change.

6.4. Relationships of motivational outcomes with motivational features, age and gender

This section discusses the results of regression modeling, first looking at overall models and then at individual variables/predictors. In essence, it addresses general (i.e. complete models) and specific (i.e. individual variables in the model) associations of motivational features and demographic factors with motivational outcomes.

6.4.1. How well did overall models predict motivation?

Mean standardised R Square values across all studies showed that the motivational features, demographic factors and other variables explained just over half (52%) of the

variance in motivational outcomes. (Standardised values adjust for the number of variables in the model and will henceforth be referred to simply as R Square). Put another way, half of the motivation was associated with the independent variables. Although the regression method cannot definitively prove this association represents a causal relationship between motivational features and motivational outcomes, findings in the literature (as reviewed) suggests such a relationship is likely. Conversely, mean R Square shows that about half of motivation was unexplained, or associated with predictor variables that were not measured. As the focus was on intrinsic motivators, it is plausible that these unknown factors are extrinsic motivators. For example, the effect of salaries and prestige associated with science careers was not assessed in *Burning Schools*. That most independent variables studied are intrinsic motivators is an important underlying point in interpretation. Three main things appear to influence the ability of models to explain motivation (R Square values): (1) whether subtle or overt outcomes were studied and whether they were measured using pre-post or post-only designs; (2) whether shows were free-choice activities; and (3) interplay of variables in the model and the subject matter.

The first thing that affected R Square was the type of outcomes and how they were measured. Excluding *Sustainability 2010* and *2011* which had anomalous R Squares as discussed below, models investigating overt outcomes explained 35% of variance in motivation change (all pre-post designs) whereas those with subtle outcomes (all post-only designs) explained 53%.

This suggests two things. One, the independent variables better explained subtle motivation, while with overt motivation lower R Square values suggest other unmeasured factors were involved. As this research focused on intrinsic motivators as

predictor variables, this suggests extrinsic motivators have proportionally more influence with overt motivational outcomes. People are always influenced by both intrinsic and extrinsic factors; it is the balance that changes in different situations. Overt motivation is more concrete and specific, it more closely relates to actual decisions, intentions and behaviour. In this case, extrinsic factors seem to play a larger role and this was reflected in the R Square values. Other variables, however, cannot be ruled out (see section 7.4.). Two, the research design may affect R Square values. Pre-post studies measuring motivation change typically had lower R Square values than post-only studies. Motivation change is a more accurate representation of the effect of the show, hence pinpointing what influences it is more difficult and results in lower R Square. It is hard to say which of these two observations – the type of outcomes or the research design – is more influential because overt outcomes were measured pre-post (change), while subtle measures were measured post-only.

The second thing that affected R Square values was whether the show was a free-choice setting not associated with school – a critical finding given science shows and other ISL activities often operate in school and public settings. As discussed in the beginning of this chapter, shows organised by schools are not free-choice settings. R Square values were typically higher in free-choice non-school settings. While free-choice is but one aspect that changes with the school setting, the role of self-determination in motivation (Deci & Ryan, 2008; Ryan & Deci, 2000) and much higher R Square values in free-choice settings where youth attended, suggest free-choice is a likely explanation for the differences in R Square observed.

For example, *HIV* and *Burning Schools* had the lowest R Square values. These low R Squares are most likely due to the pre-post overt motivation designs (as just

discussed), however they were also samples of school students in non free-choice settings. Mean R Square values across models explained: (a) 35% of variance in school samples with overt outcomes; (b) 42% in all school samples (adding *QVC*); and, (c) 56% in non-school free-choice settings, including 55% in the non-school *Burning Public* youth sample. The ability of models to explain motivation increases not only when subtle outcomes are included alongside overt outcomes (comparing a and b; as per point one), but also when the setting becomes free-choice (comparing b and c). Moreover, the trend was evident generally and when only looking at youth samples, which eliminate any effects of age. Hence, while overt or subtle motivation and pre-post or post-only designs appear to be major factors, the variables also explain more motivation in free-choice non-school settings. This shows that, when compared to non free-choice settings, outcomes from free-choice settings are more associated with intrinsically motivating features of the experience (the variables studied). While it is widely argued that people *attend* free-choice ISL activities for intrinsic reasons, this demonstrates *outcomes* from them are also intrinsically motivated.

Third, R Square values are affected by the variables in the model. Variables such as value and pre-motivation, as shown by high beta values, were consistently strong predictors of motivation. Data suggest, however, that variables like value are stronger influences on motivation in some subject areas. Probably the best example of this is *Sustainability 2011* where the model explained 78% of variance in motivation change, about 20% more than any other model and 40% more that other pre-post models, despite overt motivational measures which usually resulted in low R Square values. As noted in the results, this high value was influenced statistically by the small sample and lower variance in motivation change and probably methodologically by the type of

people who were diligent and stayed to complete the second page of the survey (almost half did not).

The model, however, also contained four variables with beta coefficients above 0.3 that have conceptual reasons for explaining motivation change (individual motivational features will be discussed in full in the next section). These included: prior knowledge and knowledge change variables that in most cases conceptually related to motivation measures (e.g. knowledge of the energy savings achieved from recycling along with motivation to recycle); value, which one would expect to be influential in motivating action on climate change; and pre-motivation, which sets the baseline for change and hence will affect how much is possible. On the other hand, *Burning Schools* also included value and pre-motivation and had the equal lowest R Square explaining 31% of variance. This suggests that while value is strong motivator of climate change related intentions in the general public, it does not exert such influence in career, study and other motivations towards chemistry in students. As discussed above, extrinsic motivators may play a larger role in students' career choices. Having few variables in the model (e.g. *HIV*) or scales with less items/low reliability (e.g. *Booming*) was also associated with low R Square.

Taken together, several factors appear to influence how well the models explain motivation. Principal amongst these is the type of outcomes and whether post-only or pre-post designs were used. Overt motivation and pre-post studies typically yielded lower R Squares; both these factors give a more accurate and specific measure of motivation so it makes sense that models explain it less well. Comparing school-based with general public shows demonstrates that the context appears to play a secondary role, with R Square higher in free-choice settings. A final factor affecting R Square,

somewhat obviously, is which variables are included in the model, however the show's subject matter appears to interact with this. Extrinsic motivation may be more influential in circumstances where R Square was lower (i.e. overt motivation and non free-choice settings), because the motivational features and the vast majority of predictors were intrinsic motivators. By the same token, where R Square was higher, intrinsic motivation plays a proportionally larger role.

6.5. Which motivational features identified were associated with motivation?

Regression beta values provide a method to determine the relative association of individual predictor variables with motivation. When comparing these variables, show presenters can manipulate them to varying degrees. Variables that can be potentially affected by show content and presentation provide the best avenues to more motivational shows. For example, pre-motivation, age and gender can only be changed by selecting specific audiences, whereas variables like surprise and value can be changed by the presentation and content of the show. Middle ground exists, for example a show could be modified to make it more valuable to males or females, or address aspects where audiences have low pre-motivation, and hence make it more motivational for them (as discussed further in Chapter 7). Nevertheless, variables that were strong predictors (high beta values) and which are practical to manipulate are of greatest interest, although all variables provide potential ways to make more motivational shows. The following section first discusses emotions and motivational variables and then demographic factors, with significant/high beta value predictors first.

6.5.1. Pre-motivation

Pre-motivation consistently predicted motivation change, with beta values showing it had the largest influence of any variable studied. Pre-motivation had an inverse relationship at the scale and item level; the higher the pre-motivation the lower the change. These findings are not surprising. As pre-motivation is the baseline for any change, where it is low there is greater potential for improvement and vice-versa. This finding shows low pre-motivation individuals experience greater motivational change from the show, however the converse is not as definite. While it is likely high pre-motivation individuals do experience less change, these measurements are more subject to ceiling effects. Potential ways to rectify this are noted in section 6.3..

Pre-motivation is not something that can be manipulated in the show like most other variables studied. That said, low pre-motivation groups could and should be specifically targeted. Moreover, if pre-motivation is measured well before the group attends, then show content can be modified to the motivational needs of the particular group. This tailored approach is recommended procedure in health interventions (e.g. Fisher, Fisher, Misovich, Kimble, & Malloy, 1996), however is uncommon in ISL settings. While this was done in an informal way both in creating and refining the HIV AIDS show, a rigorous formative evaluation was not conducted. Pre-motivation's strong relationship with motivation change underscores the importance of research informing practice and knowing one's audience and adapting. Still, the diversity of audiences and logistics of formative evaluation mean pre-motivation is a not variable that show presenters can easily utilise to create more motivational shows, although it should be considered by those managing ISL and show programs.

With regard to motivation, the results found here for pre-motivation have similarities with expectancy in expectancy-value theories of motivation. These theories posit motivation for an action is a function of expectancies of success and the value perceived in the action (Eccles, 1983; Wigfield & Eccles, 2000). Conceptually, expectancy and pre-motivation have similarities in that a person's pre-motivation is a measure of their behavioral intentions at a point in time, which will be influenced by expectancies for future success. Studies investigating expectancy often find significant and/or larger changes in motivation only occur in low expectancy participants, e.g. the relevance interventions conducted by Hulleman and colleagues (2009, 2010) reviewed in section 2.3.1. A similar relationship was found for pre-motivation in the research presented here. Pre-motivation inversely predicted motivation, or, put another way those with low pre-motivation experienced greater resulting motivation. Greater effects due to a lower starting point, as seen here, appear to be a common finding in other research, e.g. humour only increased SI in mathematics in students with low individual interest in mathematics (Matarazzo, et. al., 2010), and people with lower prior environmental attitudes experienced greatest knowledge gains when visiting an aquarium (Falk & Adelman, 2003).

6.5.2. Value

Findings in this thesis suggest value is the key variable when trying to motivate people with science shows. Value predicted motivation in every study in which it was measured. In contrast to other variables, value predicted subtle and overt outcomes equally as strongly. Moreover, *Burning Public* and *Burning Schools* show value as the only variable which predicted motivation in youth, adults and all ages subsamples, and in both public free-choice shows and school-based non free-choice shows. Apart from

pre-motivation, value consistently had the highest beta values showing it is the foremost motivator relative to other variables studied. Unlike pre-motivation, however, value can be manipulated to some extent via show content and adapting to the audience. In sum, due to its strong widespread motivational effects and ability to be influenced by show content, value is *the* critical factor in creating motivational science shows.

The perception of value is reliant on an audience member's interests, background, experiences and knowledge. The more closely show content was linked to these aspects (what is important to an individual), in addition to placing science in real-world contexts, the more powerful the motivational effects. Beta values for realworld averaged 0.12 and it significantly predicted motivation in one of two studies, whereas value averaged 0.45 and was always a significant predictor (note most value scales also incorporated real-world type items). This finding is in line with synthesis in the literature review (see section 2.3.1) that showed that as value and relevance build on general real-world contexts and become more individually specific, they have greater effects on motivation and learning.

6.5.3. Knowledge

Two types of knowledge related variables were investigated in the studies: (1) specific knowledge that conceptually related to motivation (e.g. knowledge of the energy savings achieved by recycling); and (2) generic prior knowledge, which was combined with prior experience (PEPK), which could be related to anything in the show. PEPK will be discussed in the surprise and curiosity section because it appears intertwined with surprise, in the results and the literature, and was only measured in three studies.

Specific conceptually related knowledge (and knowledge change in pre-post designs) predicted motivational outcomes (*HIV*, *Sustainability 2011*), as did self-reports of learning (*HIV*). Significant beta values (prior knowledge M = 0.22; knowledge change M = 0.23) indicate knowledge was a strong predictor, however it was only measured in three studies and not as thoroughly as other variables (in line with the focus of this research). Beta values – both mean values across studies and direct comparisons within studies – consistently indicate the role of knowledge was less associated with motivation than value. This suggests people were more motivated by what was relevant and valuable to them, than what they knew or learnt from the show.

Knowledge's role relative to other variables, however, varied from study to study. For example, in *HIV*, knowledge and knowledge change of HIV transmission methods significantly predicted motivation change (betas of 0.17 and 0.13, respectively), though had far lower betas than interest-enjoyment (0.55). In *HIV*, knowledge was measured with a single item, making findings less reliable. In contrast, in *Sustainability 2011*, knowledge and knowledge change significantly predicted motivation change (betas of 0.34 and 0.32, respectively), while none of the emotions did. In *Sustainability 2011*, knowledge was measured with a five-item scale giving a more reliable assessment. The effect of knowledge variables in these studies may be increased by the fact that the knowledge assessed conceptually related to motivation, e.g. asking about the environmental benefits of ethanol blended petrol, then asking about motivation to use it. This conceptual link is different from value which measures perceptions of generic value in show content. With value measures there is no conceptual link, i.e. items did not ask about the value people place on helping the environment through the type of petrol they use.

In sum, knowledge predicted motivation, but was not as strongly associated with motivating people as value, and had mixed results compared to emotions such as interest-enjoyment. This suggests that providing ISL environments rich in motivational features – those that highlight value and are interesting and enjoyable – is as, if not more, important than knowledge-related factors for driving motivation change (notwithstanding the relation of the two). This is an important point given researchers and practitioners are often more focused on what is learnt and taught, rather than what is valued. Beta values suggest value in particular drives motivation more than knowledge, even when the knowledge measure is conceptually related to the motivation, but the value measure is not. This finding has implications for SI models that include knowledge and value as components, as does the relationship between interest-enjoyment and value discussed below – this will be addressed in the final chapter. Nevertheless, knowledge still predicted motivation, so should not be underrated.

6.5.4. Interest-enjoyment

Interest-enjoyment was the next best predictor of motivation, with significance in half the studies in which it was measured. Interest and enjoyment combine to form the emotional component of SI, along with value and knowledge components (Hidi & Renninger, 2006). Comparing the relative effects of SI components, data presented here suggest that in science shows motivational outcomes are associated primarily with value, then knowledge (although few studies investigated it) and then interest-enjoyment. Nevertheless, that interest-enjoyment significantly predicts motivation means that science shows that provoke these emotions should have greater effects on motivation.

Two major trends emerged concerning interest-enjoyment: (1) it predicted subtle outcomes more than overt outcomes, and (2) it was more associated with motivational outcomes in youth. Interest-enjoyment beta values were non-significant in overt motivation studies except *HIV*, where it was high. Several factors could explain this. Interest-enjoyment was the only variable investigated in *HIV*, which could inflate beta values. That is, when other variables are added to a model (e.g. value) the variance in motivation explained by interest-enjoyment will decrease as other variables better predict motivation. This alone does not seem to be enough to explain the stark differences between interest-enjoyment's beta value in *HIV* (0.55, $p < 0.001$) and other overt outcome studies (-0.01 to 0.03, all non-significant). Moreover, explanations such as the seriousness of the subject matter – where one could speculate positive emotional factors play less of a role – also seem remote, as both climate change (*Sustainability 2010* and *2011*) and HIV AIDS were presented as serious issues.

A key difference appears to be the audience. Compared to Australian public and student audiences, South African school students' interest and enjoyment were more associated with motivation. This may be due to these elements being less prominent in South African learning settings, especially in HIV learning (things observed while conducting the research). It is possible the novelty of an interesting, enjoyable approach to HIV learning was a powerful way to motivate the audience.

Interest-enjoyment's greater motivational role in youth, while present, appears to be overridden by the type of outcomes. This can be demonstrated by the various studies on *Burning Issues*. Beta values were highest in *Burning Public* youth (0.24, $p = 0.000$), lower in *Burning Public* all ages (0.17, $p = 0.001$), and lower still in *Burning Public* adults (0.07, non-significant). With all other factors constant (the show and scales), a clear

trend shows interest-enjoyment predicts motivation more strongly in younger audiences. In *Burning Schools*, however, which used the same show, a slightly older youth audience, and a mixture of subtle and overt outcomes, interest-enjoyment's beta value was lower again (0.02, non-significant). This suggests that the motivational potential of interest-enjoyment is primarily determined by the type of outcomes and then by age. Even given explanations discussed above, *HIV* results still contradict this and further research is required before firm conclusions can be reached. Nevertheless, the vast majority of studies suggest that interest-enjoyment motivates subtle but not overt outcomes. This finding has relevance for ISL programs targeting youth that often emphasise interest-enjoyment aspects ('making science fun') regardless of the type of outcomes they hope to accomplish. This will be discussed in the next chapter.

6.5.5. Surprise and curiosity (and PEPK)

Surprise and curiosity are related constructs; surprise occurs when people lack schema to explain an event, which curiosity seeks new information to build (Charlesworth, 1969). As argued in section 3.1.3., surprise is likely to lead to D-curiosity as both are about information-gaps, or missing schema. This is particularly the case in the use of discrepant event demonstrations, which are presented to maximise surprise through a counterintuitive result, the mystery of which provokes curiosity making people eager to understand what has happened (see section 3.1.1.).

In two studies, factor analysis used in scale development supported this surprise-curiosity link, with items for surprise and curiosity forming one discrete factor (other support for the surprise-curiosity link will be discussed in section 6.7.2.). This tended to occur when fewer overall items were used to measure the two constructs. In these

cases, surprise and curiosity were combined into a composite measure referred to as 'surprise-curiosity'.

Surprise and curiosity predicted motivation in five of eight and five of nine studies respectively. Trends were less consistent than other variables, however the motivational potential of surprise and curiosity appears to be related to (1) show demonstrations and delivery by the presenter, and (2) whether audience members were youth or adults.

Comparing *Booming* and *Ballistics* with *Burning Public* illustrates a possible impact of demonstrations and presenter delivery on surprise and curiosity. These shows were similar in that they contained demonstrations about explosions and fire. Demonstrations in both shows had potential to be discrepant events, however, only those in *Booming* and *Ballistics* were consciously designed to maximise discrepancy – I presented these shows incorporating ideas on discrepant events and D-curiosity (see section 3.1.). Beta values for surprise and curiosity (M = 0.24) were significant and the highest of any studies in *Booming* and *Ballistics*. Surprise and curiosity mean scores were higher at 3.86. Several demonstrations in these shows were selected and presented to maximise surprise and curiosity, primarily through manipulating people's schemas and highlighting counterintuition, as discussed more in the next chapter.

In contrast, in *Burning Public* surprise and curiosity betas were lower (M = 0.08) and only significant in two of six cases, and mean scores were lower at 3.61. Although these shows contained potential discrepant events, the presenter did not consciously use techniques to manipulate surprise and curiosity. It is interesting to note, however, that although demonstrations were not structured to be maximally discrepant, some schema-manipulation techniques were used in *Burning Public*, such as building tension

where there was little if one knew the science. In informal conversation with Dr Wothers after the completion of the shows, he said these were things he had found 'worked' after years of doing shows and lectures. He used the techniques out of nous and experience, not due to underlying knowledge of the importance of surprise and curiosity. It is reassuring when research and practice reach the same conclusions.

Nevertheless, a key difference between these two shows was the way presenters selected and delivered potentially discrepant demonstrations. Surprise and curiosity significantly predicted motivation in shows where discrepant events were consciously used and presented to maximise discrepancy, however rarely predicted motivation if not. This conclusion is also supported by findings in *Sustainability 2010* and *2011*, where no discrepant events were used and surprise and curiosity were not significant predictors – though this finding could also be due to the subject matter and overt outcomes. Furthermore, in *Sustainability* deliberate efforts were made to communicate verbal information in ways that would increase surprise and curiosity, suggesting demonstrations are key to manipulating these motivational features. In sum, this suggests that the way demonstrations in particular are presented – especially discrepant events – influences emotional and motivational responses, and in turn motivational outcomes. (Note that possible effects of PEPK, which is related to surprise and was only investigated in *Burning Public*, were ruled out.)

The second observation concerning surprise and curiosity's motivational effects comes mainly from the youth/adult/all ages subsamples in *Burning Public*, however is also visible across the studies. At first glance, results from *Burning Public* appear puzzling: motivation was predicted by surprise but not curiosity in the all ages study, neither in the youth sample, and only by curiosity in the adult sample. Within group mean scores

for surprise and curiosity were equivalent in adults (3.62 and 3.58, respectively) but different in youth (3.83 and 3.40). Correlations between surprise and curiosity were higher in adults (r = 0.498) than in youth (r = 0.311). A final difference in PEPK, a variable theoretically related to surprise and curiosity, was more interpretable – PEPK was significantly higher in adults compared to youth, which is consistent with adults having greater background knowledge and experience due to age. In sum, there were four major differences between youth and adults: (1) motivational effects of surprise and curiosity; (2) relative levels of surprise and curiosity; (3) surprise and curiosity correlations, and (4) levels of PEPK. These results become clearer applying ideas from D-curiosity and information-gap models.

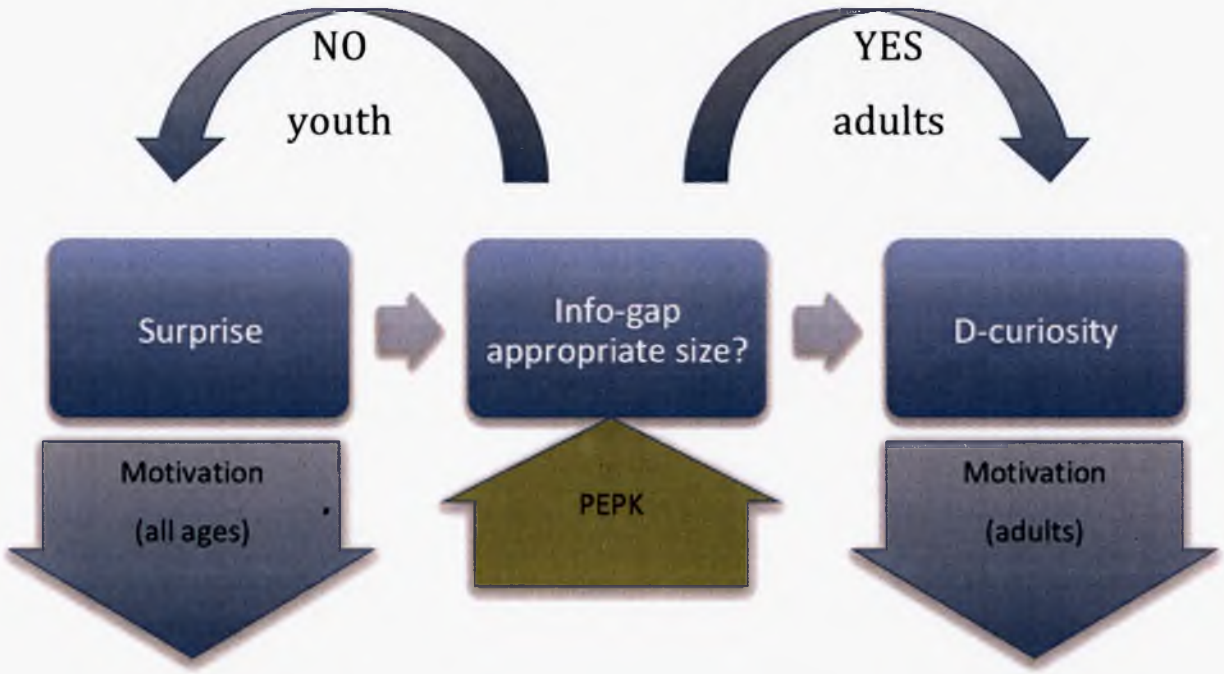

Figure 14. Proposed surprise to curiosity process for youth and adults.

Figure 14 proposes a process whereby surprise leads to D-curiosity depending on whether the information-gap created by the surprising event is an appropriate size,

based on Lowenstein's (1994) curiosity model. The process fits the differences observed in *Burning Public*. The size of the gap will depend on available schema, both in existing PEPK and new schemas provided by the presenter, as discussed below. According to Lowenstein, when an information-gap is an optimum size – that is, people perceive the gap, sense their deprivation and think the gap is not so large it is irreconcilable – this will lead to greater D-curiosity. This is the proposed process for adults. If the information-gap is too large, however, then people may not perceive the gap or if it is perceived, feel it is too large to be filled (ibid.). This is the proposed process for youth.

The size of the information-gap depends on available schema. While the presenter provides information before a demonstration that builds schemas and aids understanding, people also access preexisting PEPK-based schemas. PEPK was significantly higher in adults than in youth. This is consistent with adults typically having greater background knowledge, critical thinking skills and ability to understand show content: this was particularly true of the *Burning Public* audience that included university chemistry students and academics. (Although this was not formally recorded it was reflected in observations and comments written on surveys). These qualities mean adults have more available schema – both knowledge and tools to manipulate knowledge. More schemas create a more bounded and hence manageable sized information-gap. Size differences between youth and adults' information-gaps (as supported by corresponding differences in PEPK) explain differences in how these groups responded to a surprising, schema-discrepant event.

Results suggested *Burning Public* adults responded to surprising content by becoming curious, as supported by equivalent mean scores for surprise and curiosity, and higher

correlation between surprise and curiosity in adults compared to youth. This conversion of surprise into curiosity depends on the size of the information-gap, which was manageable for adults, and is consistent with the higher PEPK score (more schema) for adults. A significant beta value of 0.23 shows this resulting curiosity was motivational for adults. Other studies also support the finding that curiosity has greater influence on motivation in adults. Betas for curiosity are typically lower in younger audiences such as *QVC* (0.11) and higher in older youth audiences such as *Burning Schools* (0.17) and mixed age family audiences such as *Booming* (0.21) and *Ballistics* (0.29). Across the studies it appears that the motivational effects of curiosity increase with age.

Burning Public youth, in contrast, did not have equivalent scores – surprise was higher than curiosity – and they correlated less than in adults. This suggests youth perceived the schema-discrepant event, felt surprised, but did not convert surprise into curiosity as effectively as adults. Loewenstein's (1994) ideas suggest this is due to the information-gap being unmanageable; it may appear so large it is insurmountable or may not even be salient. Youth's lower PEPK scores (fewer schemas) are consistent with a larger, unmanageable gap. This leads to the lower scores reported for curiosity, and it not significantly predicting motivation in youth.

In fact, although curiosity was not a significant predictor in youth, a beta value of -0.07 shows it had an inverse relationship with motivation, possibly due to feelings of confusion associated with an information-gap that was too large. The same non-significant but negative beta value for curiosity was also seen in *Sustainability 2011*, suggesting that D-curiosity may have negative effects on overall motivation when information-gaps are too large. Non-significant beta values suggest the negative

effects of curiosity did not significantly effect motivation in theses cases, however it does point to the possibility. Too much deprivation and unmanageable information-gaps may lead to confusion, frustration and negative effects on motivation.

Returning to *Burning Public* youth, results instead suggest that in youth surprise may lead to interest (and enjoyment), as was suggested by Iran-Nejad and Cecil (1992). This is consistent with the significant and high interest-enjoyment beta value (0.24) that only occurred in youth. As discussed in section 3.1.5., while interest and D-curiosity are both information-seeking behaviours, D-curiosity is argued to motivate this more strongly (Litman, 2005; Loewenstein, 1994). Looking at motivation more broadly (i.e. not just information-seeking), this was true of adults but not youth in *Burning Public*: in adults D-curiosity but not interest-enjoyment predicted motivation, however the converse occurred in youth. Other studies also suggest that age is the critical factor as to whether D-curiosity or interest-enjoyment has greater effects on motivation. D-curiosity was more motivational than interest-enjoyment in adult and secondary student samples (*Burning Public* adults and *Burning Schools*), but the reverse was true in younger, primary student samples (*Burning Public* youth and *QVC*). The model proposed here suggests that these differences may be due to information-gap sizes, in which case findings may be different had optimum sized information-gaps been created in youth, i.e. D-curiosity may have been more motivational. Differences may, however, also reflect fundamental distinctions in the kinds of motivational states prevalent in different age groups. No previous research has investigated D-curiosity in youth.

Burning Public all ages had different predictors again: PEPK (inverse relationship) and surprise were both significant. As argued above, different information-seeking

behaviours appear to follow surprise in youth and adults: interest and curiosity, respectively. That is, surprise's motivational effects are mediated either through interest or curiosity in these groups. It is possible that in the combined sample these mediated motivational effects are hidden or offset each other, instead showing up as a direct motivational effect of surprise. As surprise is dependent on available schema, when it is a significant predictor, variables like PEPK (a proxy for schema) may play a complementary role. This would explain PEPK's significance in the combined sample.

PEPK's negative beta value is consistent with this complementary role; lower PEPK and hence higher surprise predicted motivation. The initially odd finding that PEPK had a non-significant small correlation with motivation, yet was still a significant predictor of it, makes more sense viewed in this fashion – PEPK appears to be operating inversely and in tandem with surprise (as also suggested by the sub-question analysis). PEPK may also have a direct inverse effect on motivation, for example people with higher PEPK should be less motivated to seek more information. Similarly, higher PEPK in the domain of science suggests already positive motivation towards science and hence less change. That said, PEPK did not always have an inverse relationship with motivation, such as in *Burning Schools*. In that study, PEPK positively predicted motivation, most likely for two reasons: (1) the composite surprise-curiosity scale was heavily weighted towards curiosity, reducing the potential for a complementary inverse role for PEPK; and (2) the motivation scale measured study and careers aspects in secondary school students – levels of PEPK in students are not likely to be high enough to mitigate motivation in ways argued above, as they might in an adult with prior chemistry knowledge (as found in the *Burning Public* sample). (Wider relations between PEPK, surprise, curiosity and interest-enjoyment will be discussed further in section 6.7.).

In sum, processes proposed in the literature about the relationship of surprise, D-curiosity, PEPK and information-gaps are able to explain results that initially appear atypical. Results and processes outlined above suggest that: in youth, surprise leads to interest which motivates; in adults, surprise leads to D-curiosity which motivates; and in a combined sample surprise complemented by PEPK is directly motivational. Moreover, I suggest the size of the information-gap (informed by PEPK) is a critical factor that determines the type of information-seeking behaviour adopted to resolve surprise – optimum sized gaps create more D-curiosity. While these ideas are congruent with established theory and results, further research with more focused methods is required to confirm them.

6.5.6. Immediacy

Immediacy only predicted motivation in two studies, *QVC* and *Burning Public* youth, which both had young audiences and subtle outcomes. Compared to these youth studies, beta values for immediacy were lower in family audiences and lowest in adult audiences (*Burning Public* adults), supporting the finding that motivational effects of immediacy diminish as age increases. In studies on youth with overt outcomes (*Burning Schools*) immediacy was not a significant predictor. There is a clear trend of immediacy being associated with subtle motivational outcomes in youth, but only under these conditions.

Immediacy is a composite measure combining various factors that enhance closeness between audience and presenter, including (in this research) enthusiasm, humour, interactivity and involvement. This family of variables are combined in the literature, and grouping in factor analyses that were conducted during scale development also supported this. Factor loadings occasionally showed co-loading between immediacy

and interest-enjoyment suggesting they are related (this will be discussed further in section 6.7.4.). Being a composite measure, it is difficult to say which facets of immediacy are most motivational. The literature implicates interactivity and involvement, which have been shown to be SI 'hold' factors which lead to sustained SI (Mitchell, 1993). Again, this points to a relationship between immediacy and interest-enjoyment.

Along with young audiences, the role of interactivity and involvement may explain findings for immediacy in the two studies where it significantly predicted motivation. In *QVC* (immediacy beta = 0.29 – the highest in any study), four of seven items in the immediacy scale measured interactivity and involvement as these aspects were hypothesised to be more important in the potentially disconnected medium of the video conference. In *Burning Public* youth (immediacy beta = 0.19), two of six items measured interactivity and involvement. The immediacy scales' weighting toward interactivity and involvement may explain immediacy's larger beta value in *QVC*.

The video conference medium may also have increased the motivational effects of immediacy. It makes sense that behaviours that build closeness and connection with the audience will be more critical in a physically disconnected environment. Other video conference learning research has found immediacy increased student's learning and satisfaction (Hackman & Walker, 1990), which provides some support for this claim. In addition, immediacy's beta in *QVC* may be inflated by the omission of value – this is likely to play a significant role – although would be slightly offset by the presence of realworld in the study. As value is such a strong predictor in other studies, omitting it allows less strong predictors to explain more variance in motivation.

In summary, immediacy appears to be a stronger motivational feature in youth when subtle outcomes are assessed. Its effects were weaker in adults and when overt outcomes were studied. Results suggest that the interactivity and involvement aspects of immediacy may have greater association with motivation, which is consistent with previous research on SI. Immediacy may be more critical in video conference formats, although findings across the studies suggest age is the overriding factor: youth are more motivated by immediacy than adults.

6.5.7. Age

Age had an inverse relationship with motivation: the older audience members were, the less the show motivated them. In all but two studies, age was a significant predictor with negative beta values. Beta values were typically larger (more negative) in family audiences where there was greater variance in age, however were still significant in youth samples albeit with smaller beta values. This shows that regardless of whether age range was small (students) or large (families), being older was associated with less motivation. In the *Burning Public* subsamples, age was not a significant predictor in adults, but was in all ages and youth. Moreover, compared to adults, age's beta value was greater (more negative) in all ages, and greater still in youth. Hence, youth accounted for most of age's effect in the all ages sample, though as many of the adults in *Burning Public* were not in family groups (unlike other public shows) it is unclear if this effect operates in all audiences.

HIV also returned a non-significant result for age, which contrasts with other student sample studies. Initially it was thought that variance in motivation associated with age was instead being captured by pre-motivation, as these two variables are likely to be correlated (i.e. sexual activity will increase with age). The hierarchical regression,

however, showed age's beta value was consistent regardless of whether pre-motivation was included in the model, which rules out this possibility. This means, unlike most studies, the HIV show had the same motivational effect regardless of age. This is a welcome finding given that in all the studies looked at, motivating older students who are more likely to be sexually active and hence at risk is crucial in the HIV show.

Several possibilities exist for age's inverse relationship with motivation. The most likely explanation based on results is adults' higher levels of prior motivation; that is, their baseline is higher so there is less opportunity for positive changes. As shown by negative betas for pre-motivation, the higher the initial motivation is, the less change occurs. Accordingly, results from *Sustainability 2011* showed adults had significantly higher pre-motivation and experienced significantly less change compared to youth. In other words, the older people were, the more motivated they were prior to the show and hence they had less scope to become more motivated – an issue compounded by ceiling effects when using scales for measurement. Similarly, other factors that increase with age such as prior knowledge may result in less motivation. Motivation items measuring information-seeking/further thought should be lower when people already possess such knowledge – something that is likely to accumulate with age. More general features that increase with age, such as being more set in one's ways with firmer beliefs and motivations that are resistant to change, may also explain this trend.

Another possibility is that shows provoke different emotions and motivational variables in different ages, which in turn affects motivation. *Burning Public* t-tests indicate that apart from value and interest-enjoyment, all other variables were

significantly different between youth and adults. Moreover, apart from value, different variables predicted motivation in youth and adults. For adults, curiosity was the only other variable that predicted motivation, however for youth interest-enjoyment, immediacy, gender and age were all additional predictors. This shows that different ages report different levels of motivational features, and suggests they have different effects on motivation depending on age. Motivation was associated with many of the variables studied in youth, but few in adults (only value and curiosity). One way to interpret this is that the motivational features studied here become less effective motivators as age increases. It suggests that other factors play a greater role in adults. Determining what these are, especially for the underrepresented 15 to 30 year old age group, should be a priority for future research.

Two final contributing factors may play a role in the inverse relationship between age and motivation. One is measurement effects, i.e. that younger people are more likely to give exaggerated scores on motivation, whereas older people are more conservative and realistic. In addition, motivation scales were quite general so they were appropriate to everyone, but were probably more geared towards youth. Very different results may occur if a separate adult motivation scale were used instead, tapping outcomes that relate to the goals and identity of adults (e.g. bringing their children to more shows in future). The second contributing factor is that while having content that appeals to different ages was considered, the majority of show content was designed with younger audience members or the family group in mind. Hence, one would expect to see greater motivation in younger segments of the audience.

In sum, motivation's decline with age is likely to be due to a combination of factors. Adults' higher pre-motivation and prior knowledge – as reflected in the data – are

likely to play a major role. Adults have established motivations that may be more resistant to change. Youth/adult differences in levels of motivational features, and in which features predicted motivation, may also underlie the decline of motivation with age. Finally, both the shows and survey instruments were designed primarily for families and youth, so this may contribute to lower actual and measured motivation in adults.

6.5.8. Gender

Gender effects were not widespread. Gender predicted motivation in four of ten studies including *Booming*, *Burning Public* all ages and youth, and *HIV*. In all cases being male was associated with greater motivation. These results are not surprising for *HIV* given the broad gender differences in HIV related behaviour reported in the literature as discussed in section 4.3.6.. The *HIV* show was unique in that behaviours the show aimed to motivate differed substantially between genders. This was reflected in the results – males had significantly lower pre-motivation scores and greater motivation change. This suggests that gender has both direct and indirect effects. That is, some of the gender difference in motivation change was associated with simply being male, while some was associated with males' lower pre-motivation scores. Beta values (0.08 for gender and -0.84 for pre-motivation) suggest gender differences in pre-motivation are likely to play a greater role in motivation change. In other words, while being male was associated with greater motivation change, this is primarily due to lower pre-motivation scores in males and hence greater potential for positive change.

That gender predicted motivation in *Booming* and *Burning Public* all ages and youth subsamples but not other studies is more puzzling. In these studies, being male

predicted greater motivation. The role of the presenter's gender, which was male in all these shows, can be discounted as this was not observed in any other male-presenter studies. One other thing these three shows had in common was they all focused on explosions, combustion and similar chemistry demonstrations. This type of content is often stereotypically touted as 'boys stuff' and may explain the greater motivational effects these shows had on males. Other research suggests that girls are less attracted to physics and chemistry in general (see discussion in section 7.3.; Hoffmann, 2002). As the result was not seen in *Burning Public* adults, it follows the effect is mainly confined to youth. It appears that explosions, fire and the like may be either more motivational for young males, hinder motivation in young females, or both. The implications of these findings will be discussed in the next chapter.

6.6. Key findings regarding the role of motivational features, age and gender

The above sections show which motivational features and audience characteristics were associated with greater motivation. As discussed in section 4.8., the research design does not conclusively prove the motivational features are causing motivation, but regression findings, in combination with literature showing these features have been motivational in similar settings, mean a causal effect is quite likely. Some motivational features and other variables can be manipulated thorough show content and presentation, while others are largely beyond the control of the presenter. While they all have potential application in creating motivation from science shows, it is those in the former category that are of most importance for practitioners.

Beta values suggest the relative importance of the main variables in influencing motivation is (highest to lowest): pre-motivation, value, knowledge, interest-

enjoyment, age, surprise and curiosity, immediacy and gender. The position of knowledge is less certain than other variables as it was not measured in as much depth and only in three studies. As discussed in the previous sections, most variables' motivational potential appears to be highly affected by specifics of the show – such as audience, content and presentation – with three exceptions. Pre-motivation and value (all studies) and age (all but one study) predicted motivation reasonably consistently. As pre-motivation and age are somewhat out of the control of presenters, this leaves value as a critical motivational feature regardless of the type of show, desired outcomes, or audience. Making people perceive more value in show content, however, is not a straightforward task. Of all the variables studied value is the most subjective, moreover we have very little idea of how people perceive value in science. This will be discussed further in the next chapter.

Of the remaining motivational features, several overarching trends regarding how they affected different ages and different types of outcomes are evident. Interest-enjoyment and immediacy seem to work together, and were better predictors of motivation in youth and when subtle outcomes were studied. The similarity of interest-enjoyment and immediacy's motivational effects may well be associated with their relation to each other – indeed, this was brought up by the literature review that suggested that immediacy's motivational effects might work via interest and enjoyment. Several other results support an interest-enjoyment and immediacy relationship, such as co-loading of immediacy and interest-enjoyment items in factor analysis, and the relation between interactivity and involvement (part of immediacy), interest and motivation found in this research and elsewhere (e.g. Mitchell, 1993). The interest-enjoyment and immediacy relationship will be addressed in section 6.7.4..

Conversely, when it came to motivating adults and older students, or considering overt motivational outcomes, interest-enjoyment and in particular immediacy appeared ineffective – but curiosity was not. Findings suggest that adults had greater capacity to generate curiosity following a surprising event and this curiosity affected motivation (the surprise-curiosity link will be discussed further in section 6.7.2.). Information-gap and I/D models of curiosity were helpful in understanding possible mechanisms. Further evidence validating the I/D-curiosity distinction will be presented in section 6.7.1.. Curiosity influenced both subtle and, to a lesser extent, overt outcomes. Value and knowledge, however, were far more consistent at motivating overt outcomes.

6.7. Sub-questions emerging from the literature review

Section 3.4.1. posed several sub-questions that addressed gaps or areas of contention in the literature. These questions essentially deal with relationships between the motivational features, both association and independence. Answers to the sub-questions are critical for understanding the overall picture of science show motivation. While the main research question addresses which motivational features were directly associated with motivation, it is still unclear if the motivational features influence each other, and hence influence motivation indirectly. For example, although immediacy was only motivational in two of nine studies, does immediacy influence other motivational variables, which then influence motivation? For these motivational features to be most useful for practitioners, it needs to be clear not only what is directly motivational but also what the upstream influences on each feature are, or which features operate independently. Other sub-questions are more theoretical in nature, such as asking if models are accurate (i.e. I/D-curiosity). Questions like this are

useful in providing a sound theoretical framework in which to view science shows, which in turn suggests methods to improve them.

6.7.1. Is the I/D-curiosity distinction valid during a learning experience like a science show?

As discussed in section 3.1., recent models of curiosity may be useful in interpreting the experience during a science show, particularly in understanding discrepant events. The I/D model of curiosity (Litman & Jimerson, 2004) divides curiosity into D-curiosity, in which tension and intrigue due to missing information drive information-seeking, and I-curiosity, in which information-seeking involves feelings of interest and enjoyment. Research on these constructs has focused exclusively on measuring traits (i.e. retrospective qualities of the individual and personality) as opposed to states (i.e. during the actual curiosity experience). The majority of research has been conducted on university undergraduates, with only one study looking at the general public. Research in this thesis builds on this by looking at the state experience of curiosity in a general public sample.

Data suggests that I- and D-curiosity, as proposed by Litman and colleagues (2004, 2008), are operating during a science show. Analyses show I- and D-curiosity are distinct but related constructs. Factor groupings in *Burning Public* all ages (and conducted during scale development for other studies) showed the public differentiated feelings of interest, which they associated with enjoyment and fun (I-curiosity), and feelings of curiosity, which they associated with information-gaps, deprivation and unresolved questions (D-curiosity). The audience associated the term 'curiosity' with D-curiosity conceptualisations. This is important, as these factor groups show that the audience conceptualises curiosity primarily as D-curiosity, and interest

as distinct from this – researchers need to also observe these distinctions, yet often do not. Regression findings supported the distinction of I- and D-curiosity: curiosity did not predict interest-enjoyment, or vice-versa.

While distinct, the two constructs were somewhat related. This was shown through co-loading of the curiosity item onto the interest-enjoyment (lower loading) and D-curiosity (higher loading) factors when all other motivational features except surprise were omitted from the analysis. There was also a significant correlation ($r = 0.28$) between interest-enjoyment and D-curiosity. This correlation was lower than in studies by Litman and colleagues (2008, 2011) who found correlations of 0.80 in university students and 0.68 in non-students using trait measures. This is probably due to the scales in this thesis conceptualising interest-enjoyment as a broader emotional experience rather than being specific to information-seeking, and investigating states as opposed to traits.

Taken together, the findings in this thesis support the application of I/D models of curiosity to science shows and other ISL settings, although specific future research should refine and confirm this. Moreover, data show that interest and curiosity are qualitatively different – the former is about enjoyment and fun, whereas the latter is about missing information. Analyses show that the audience differentiate between interest and curiosity on this basis. It follows that researchers and practitioners should do the same, which is currently lacking in some areas of psychology and formal and informal learning. The wider implications of this, the fruitfulness of applying I/D models to science shows and discrepant events, and implications for presenters will be discussed in the next chapter.

6.7.2. Is surprise linked to D-curiosity, SI or both?

As noted in section 2.5.3., researchers have associated surprise with the emotion of interest and SI (Dohn, 2011a, 2011b; Iran-Nejad & Cecil, 1992; Silvia, 2005b) as well as curiosity (Charlesworth, 1964, 1969). It is possible surprise acts on all these constructs, or that different age groups employ different information-seeking behaviours following surprise, as suggested by the model proposed in section 6.5.5.. Another possibility is that these researchers' apparently contradictory views are due to failing to differentiate between interest and curiosity, or not using terminology strictly when making claims about the effects of surprise.

The findings of sub-question one above, however, show interest and curiosity are different. So which does surprise act on and to what degree? The question is particularly relevant for science shows, which often employ discrepant event demonstrations which are widely agreed to provoke surprise initially and then interest and/or curiosity – however none of the literature in this area acknowledges the latter two are different (e.g. Liem, 1987). If presenters want to manipulate different motivational features accurately, they have to know which triggers – like surprise – will lead to motivational states like SI or curiosity.

Analysis of *Burning Public* all ages shows a consistent and strong relationship between surprise and curiosity, while the relationship between surprise and interest was weaker and not supported by all analyses. Regression analysis supports the hypothesis that surprise provokes both D-curiosity and interest, however D-curiosity is provoked more strongly. Surprise predicted both, but beta values were about three times higher for predicting D-curiosity compared to predicting interest-enjoyment. Value, another component of SI, was not predicted by surprise, which suggests that any effects of

surprise on SI come through SI's interest-enjoyment (emotion) component. Correlations also support the stronger relationship between surprise and D-curiosity; correlations for surprise with curiosity (r = 0.40) were higher than with interest-enjoyment (r = 0.26) and value (r = 0.12).

Factor analysis (see section 5.6.2.) was able to flesh out surprise's relationships and show which underlying appraisals of surprise were primarily responsible for its link to D-curiosity. All factor analyses showed surprise was distinct from interest-enjoyment and value. Although the initial factor analysis yielded discrete factors for surprise (with PEPK) and D-curiosity, iteration two (with motivation removed) suggested that the item measuring schema-discrepancy was involved in linking surprise and D-curiosity. The schema-discrepancy item, which had originally formed a factor with the surprise and PEPK items, instead joined the D-curiosity factor and co-loaded onto the surprise/PEPK factor. The item measuring unexpectedness also co-loaded, however had much higher loading on the surprise/PEPK factor than the D-curiosity factor.

Hence, schema-discrepancy appears to be the critical link between surprise and D-curiosity. This is consistent with the theoretical point made in section 3.1.3., that is, a common characteristic of surprise and D-curiosity is a lack of available schema.. These results show that schema-discrepancy, or in the parlance of Charlesworth 'misexpectness', is what links surprise with D-curiosity. How presenters can maximise schema-discrepancy, which should foster surprise and D-curiosity, will be discussed in the next chapter.

The final factor analysis conducted with items for surprise, curiosity and PEPK resulted in a two-factor solution with surprise and curiosity items in factor one, and PEPK and co-loaded surprise items in factor two. That surprise and curiosity items formed a

single factor is further evidence of the close relationship they share. This single factor solution also occurred in *Booming* and *Burning Schools* (where combined surprise-curiosity scales were hence employed), where only four items measured both surprise and curiosity.

Taken together, analyses show that surprise has a weak relationship with interest and SI and a strong relationship with D-curiosity, which is linked to surprise through schema-discrepancy. These findings are consistent with the arguments presented by Charlesworth (1969) and the view that surprise leads primarily to D-curiosity.

6.7.3. Are the theorised links between PEPK and surprise, PEPK and curiosity and PEPK and value reflected empirically?

Despite the close relationship between surprise and curiosity, overall analysis suggests that PEPK is only related to surprise. All forms of analysis show an inverse relationship between PEPK and surprise – as PEPK decreases, surprise increases, and vice-versa. This is shown by: negative PEPK-surprise correlations; combined PEPK/surprise factors with opposite valance loadings for surprise and PEPK items; and, surprise and PEPK significantly predicting each other, but with negative beta values. Notwithstanding their subject, these results are unsurprising – they are consistent with the idea that surprise involves an appraisal that compares the event against existing schema (Charlesworth, 1969; Meyer & Reisenzein, 1997). As argued elsewhere, the PEPK measure in this thesis is a proxy for schema; our previous knowledge and experience is what our schemas are built on.

PEPK's independence from curiosity was less expected; the finding clashes with synthesis in section 3.1.4. which posited PEPK may influence curiosity because it informs the size of information-gaps. It is possible that PEPK influences surprise which

then influences curiosity – surprise is the mediating construct – but the analysis suggests there is no direct relationship between PEPK and curiosity. This was shown by non-significant curiosity-PEPK correlations (noteworthy given only three pairs of motivational features showed non-significance) and PEPK and curiosity not significantly predicting each other. This independence suggests it is more likely that information given by the presenter plays a bigger role than PEPK in locating boundaries for information-gaps.

The final iteration of factor analysis using surprise, curiosity and PEPK items also cast doubt on a direct curiosity-PEPK relationship. As noted above, this analysis yielded a surprise-curiosity factor, and a PEPK factor with co-loaded surprise items (unexpectedness and surprise). There was no co-loading between PEPK and curiosity items and, moreover, the schema-discrepancy surprise item that linked surprise and curiosity did not co-load. Taken together, this shows that while PEPK is related to surprise, it not related directly to curiosity.

PEPK is however strongly related to value, with a positive relationship, consistent with literature reviewed in section 2.3.2.. The two constructs, while related, are quite distinct. Factor analysis showed co-loading of PE onto the value factor only occurred in one iteration and discrete factors – PEPK with surprise and value on its own – resulted in all other analysis. What this shows is that the two constructs are internally consistent – value items and PEPK items are most closely related to each other – however this is not to say they have no relationship. PEPK-value correlation, which was comparatively high ($r = 0.40$), did suggest a relationship – this was seen prominently in regression analysis.

PEPK predicted value (beta = 0.31) and value strongly predicted PEPK (beta = 0.44). This difference in reciprocal beta values is probably due to the number of other motivational features that significantly predicted each variable – PEPK was predicted by two variables, whereas value was predicted by four. Having more significant predictors with an overlap in the variance they explain will result in lowered beta values across all predictors – as observed with predictors of value.

The reciprocal findings, however, also raise the question of the direction of influence between PEPK and value. People may perceive value in an area because they have PEPK in that area, or people may have PEPK in an area because they find it valuable and hence gathered knowledge and experience related to it – most probably both. Although it is clear that value and PEPK are intimately related, precise knowledge of how they interrelate is scarce in the literature. Given the large role of value in motivation found in this thesis, understanding exactly what function PEPK plays in perceptions of value should be a topic for future research. A wider research agenda on value will be discussed further in the next chapter.

Taken together, the analysis shows a strong positive relationship between PEPK and value. This finding adds quantitative evidence for this claim often argued in the literature and reinforces the old adage that content should be linked to people's PEPK. Data here suggests that if it is, then people will find it more valuable, and this will be always be motivational. Implications for practice will be discussed in section 7.2.3..

6.7.4. Is immediacy a motivational variable in its own right, or are its effects mediated via another motivational variable or emotion(s) as suggested in the literature?

As discussed in section 3.2., science shows are a motivational environment where the presenter plays a central role in motivating the audience. Behaviours that build

closeness and connection between audience and presenter – immediacy behaviours – may therefore be important to motivation. Results addressing the main research question (see section 6.5.6.) show immediacy only predicted motivation in two studies with younger audiences where subtle motivational outcomes were measured. In these circumstances only, immediacy was directly motivational. Interest-enjoyment was also a significant predictor in both of these studies.

The literature on immediacy (see section 3.2.) suggests that its motivational effects may work by evoking the emotions of interest and enjoyment, which then have a motivational effect. This conclusion was common to all three aspects of immediacy reviewed and studied – presenter enthusiasm and likeability, humour, and interaction and involvement. Despite the key role that human interactions play in many ISL settings, especially science shows, it is unknown whether immediacy and interest and enjoyment have a similar relationship during ISL.

Results summarised in section 5.6.4. show a strong relationship between immediacy and interest-enjoyment. Regression analysis showed immediacy was a significant predictor of interest-enjoyment; the beta value (0.45) was the highest of any recorded in regression of the motivational features onto one another. Correlation between immediacy and interest-enjoyment was also the highest of any relationship ($r = 0.53$). Factor analysis results supported this strong relationship and indicated which aspects of immediacy were most responsible for the link.

Immediacy items measuring presenter likeability and enthusiasm appear to be most closely related to interest-enjoyment, however all items showed significant association. Enthusiasm and likeability had higher individual item correlations and co-loaded on the immediacy and interest-enjoyment factors during some factor analyses.

Co-loading suggests that these presenter-related immediacy items were sometimes more closely associated to audience interest and enjoyment than to the other four immediacy items. Reviewing item wordings shows that these co-loaded items are conceptually quite distinct; they refer to evaluations of the presenter, while the interest-enjoyment items refer to the audience's emotional response to the show. The analysis suggests these things are intimately linked.

These two immediacy items showing closest association both measured audience judgments of the presenter in particular (only one of six others, 'feel part', referred to the presenter), while other items measured immediacy behaviours more related to show content, such as humour. The data suggests that aspects of immediacy that were direct qualities of the presenter had the greatest effect on audience interest and enjoyment, which is consistent with the core idea of immediacy building audience-presenter connections. There may also be a reciprocal effect, that is, the audience found the presenter more likeable and perceived him as more enthusiastic because they were experiencing interest and enjoyment during the show.

The process of emotional contagion (Hatfield et al., 1994) can explain the results found here. Formal education research, which noted the similarities between enjoyment and enthusiasm, found the transfer of enjoyment from teacher to students is mediated by teacher enthusiasm (Frenzel et al., 2009). Although presenter enjoyment was not measured in the current research, a similar relationship between presenter enthusiasm and audience enjoyment was found. It appears the presenter's enjoyment during the show, which has behavioural markers highly similar to enthusiasm (ibid.), is transferred to the audience consistent with emotional contagion theories. Wider

implications of emotional contagion between presenter and audience will be discussed in the final chapter.

In contrast to the study by Freznel and colleagues, the current research investigated both enjoyment and interest and found higher correlations between enthusiasm and interest ($r = 0.33$) than enthusiasm and enjoyment ($r = 0.24$), albeit using single item correlations. The same pattern was seen in likeability correlations; likeability and interest ($r = 0.41$) was higher than likeability and enjoyment ($r = 0.37$). This result suggests that interest may be more prominent in the audience response to enthusiastic and immediate presentation, however overall analyses suggest enjoyment also plays a major role. This fits with interest and enjoyment often occurring in tandem (Izard & Ackerman, 2000).

It is unclear if the presenter's interest during the show also transfers via emotional contagion; while the immediacy items are a reasonable proxy for presenter enjoyment, and this assumption is supported by other research, they are not such a direct fit with presenter interest. Exploring aspects of immediacy such as the presenter's 'passion' or enthusiasm for the subject matter may uncover more connections between immediacy and interest. Moreover, as recent research has suggested enthusiasm for teaching and not enthusiasm for subject matter is the critical aspect for higher quality teaching (Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011), it would be worth exploring this distinction within ISL – settings where passion for the science seems paramount.

In sum, the data support immediacy influencing interest-enjoyment, which then usually influences motivation, in line with the literature in formal learning. All analyses of *Burning Public* all ages supported this conclusion. Looking at all the studies in this

thesis, the majority with higher beta values for immediacy also had higher beta values for interest-enjoyment, and predominantly interest-enjoyment then predicted motivation. There were exceptions, for example *Sustainability 2010* regressions onto motivation had a high immediacy beta (0.14) and a low interest-enjoyment beta (0.03), possibly due to the overt outcomes being measured or the subject matter (see section 6.5.4.). Nevertheless, the overwhelming majority of data suggests immediacy has a positive effect on enjoyment and especially interest, which then motivates.

6.7.5. Overall relationships of the motivational features

Figure 15 shows a summary of relationships of the motivational features in *Burning Public* all ages, based on significant predictors in regression analyses. Relationships addressed in the sub-questions are emphasised. Features that predicted motivation in youth, adults and all ages are also included. Immediacy and interest-enjoyment were strongly related, especially through presenter qualities including enthusiasm and likeability. PEPK was related to value, inversely related to surprise, and not related to curiosity. Surprise had a strong relationship with D-curiosity – they were linked through schema-discrepancy – and a weaker relationship with interest-enjoyment. Directionality (or causality for that matter) cannot be proven from the regression method, so arrowheads in Figure 15 are based on relationships found in the literature (e.g. that immediacy affects interest-enjoyment) and/or deduction (e.g. surprise must occur before D-curiosity). As noted earlier, there may be reciprocal relationships between some features.

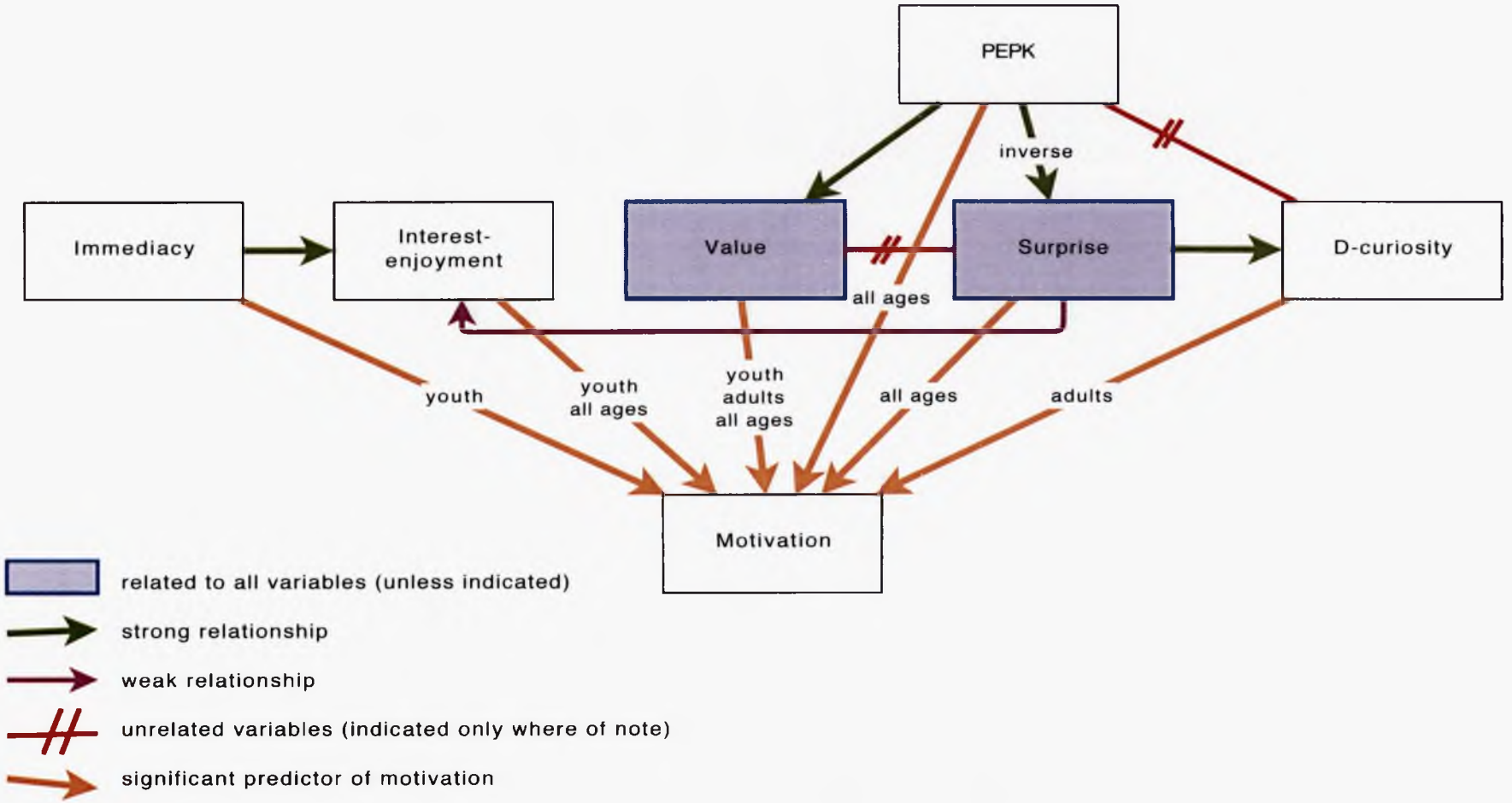

Figure 15. *Burning Public*: motivational feature relationships (all ages) and predictors of motivation in youth, adults and all ages.

Value and surprise were more interrelated than the other motivational features. Regression analysis showed they predicted and were predicted by every other variable except each other. This suggests that both surprise and value may work in combination with all the other features (bar each other), which is plausible. As discussed in section 2.5.3., surprise works in conjunction and blends with other emotions and motivational states. Regression results suggest that surprise leads to information-seeking behaviours (i.e. interest or curiosity) to make sense of the surprising event, however immediacy was also predicted by surprise. It is possible surprise is working in conjunction with emotions such as enjoyment to create an effect on immediacy, similar to a combination of surprise and enjoyment causing delight reported by several authors (e.g. Kumar, Olshavsky, & King, 2001). Some researchers (e.g. Vanhamme, 2000) also argue surprise amplifies subsequent emotions and states. While the amplification hypothesis cannot be properly tested through this data, the fact that surprise predicts all other features except value does support it – regression suggests when surprise was higher, so were the other motivational features (excluding PEPK and value).

Value also seems a likely candidate for an amplification role. When content is perceived as valuable, it stands to reason that people will feel more intense emotions concerning it, or engage in greater amounts of information-seeking behaviours regarding it. In contrast to surprise, which is likely to have a one-way relationship, value relationships are most likely reciprocal or even a positive feedback loop, i.e. people have strong emotional response to something, hence perceive it more valuable, and vice-versa. In sum, the wider interrelations seen for surprise and value suggest they are particularly important motivational features during a science show,

especially value which also consistently predicted motivation. Moreover, it underscores the importance of PEPK, which had a strong relationship with both surprise and value.

In the following chapter, these relationships between the motivational features will be integrated with answers to the main research question to draw overall conclusions and their implications for research and practice.

Chapter 7. Conclusions and implications

This thesis has explored motivational aspects of science shows. It has established that science shows can motivate people and identified features within them that contribute to motivation. It has also studied relationships between those motivational features. This final chapter begins with summaries of the major findings with respect to the main research questions and sub-questions. Following that, implications, recommendations and future research leading from this research are discussed, including the relevance of findings to the literature and most importantly to science show presenters and ISL providers. These aspects are structured around (1) the motivational features studied, (2) differing effects of motivational features on different audience segments, and (3) other unstudied features that are avenues for future research. Limitations arising from the research will then be discussed. Recommendations for future research and practice are discussed in context throughout, with a précis in section 7.6.. Finally, overall implications of this research are discussed.

7.1. Answers to the research questions

Findings across the studies show that science shows can motivate people. Different shows and show presenters were consistently able to positively influence motivation in different audience segments and contexts. Shows were able to influence both subtle, attitudinal measures of motivation and overt, behavioural intention measures. Moreover, the motivational features identified in the literature review were all associated with motivation in at least some cases, however this differed between audience segments and shows (as discussed more below). The relative importance of

the features for motivation, as suggested by regression results, was pre-motivation, value, knowledge, interest-enjoyment, surprise and curiosity, and immediacy. Pre-motivation is, however, not manipulable through show content and delivery (though may be utilised other ways, as below). Age was significantly related to motivation, which declined with age, however gender had only marginal effects: when certain types of show content were included younger males experienced greater motivation.

The motivational features were interrelated. There were close relationships between immediacy and interest-enjoyment, PEPK and surprise, PEPK and value, and surprise and D-curiosity; however the relationship between surprise and interest-enjoyment was comparatively weaker. Both value and surprise were related to all the other features except each other, suggesting these variables are of greater importance and may amplify or otherwise interact more broadly with other features. Interest-enjoyment and D-curiosity were distinct constructs. Understanding both the direct effect of features on motivation and their relationships with each other was critical to obtain a full picture of motivation during shows.

7.2. The motivational features investigated

Based on a synthesis of the literature, this thesis examined motivational features most likely to influence people during science shows. The main variables were value, surprise, curiosity, interest-enjoyment and immediacy. The following sections address conclusions and implications related to these variables, and also include associated variables such as PEPK and knowledge where relevant. Two overarching issues related to using these features – strategic use and knowing your audience – are discussed first.

7.2.1. Strategic use of motivational features

This thesis identified some motivational features within science shows, so how best to use them? Perhaps a better question is when to use them. One may be tempted to pack a show full of motivational features, however this may not always be the most effective way to achieve specific outcomes. If motivational features are used haphazardly and at every possible opportunity, the audience may be distracted from the central messages in the show. This conclusion is supported by research on interest which suggests that in some cases audiences are diverted from key messages by so-called 'seductive details' (highly interesting yet unimportant details), although such studies report mixed results (cf. Schraw & Lehman, 2001). Disciplined focus on key messages is important in any communication, but particularly for science shows, as observed by one of the fathers of the genre, Michael Faraday:

> No breaks or digressions foreign to the purpose should have a place . . . [and] no opportunity should be allowed . . . in which their minds could wander . . . Digressions take the audience from the main subject and then you have the labour of bringing them back again (if possible). (Quoted in Murray, 2007, p. 6425).

Motivational features should be closely tied to key objectives for the show, be they to educate, motivate, change behaviour or otherwise. Using motivational features in this targeted way is described here as *strategic use* – an idea that borrows from formal learning theorists as touched on in section 3.2.2. and discussed further below. Formal learning theorists (Malone & Lepper, 1987) have also distinguished motivational features as 'endogenous' (an fundamental inseparable aspect of the communication) or 'exogenous' (essentially 'tacked on' to the communication). For example, the

motivational feature of surprise is endogenous to a discrepant event, while humour associated with the discrepant event is more likely to be exogenous. Although strategic use may be either endogenous or exogenous, strategic use of endogenous motivational features is the best-case scenario. While this discussion focuses on motivation as an outcome, the same ideas apply to shows that aim to educate in specific areas, such as a curriculum linked show delivered in a school, or other targeted outcomes.

Strategic use is paramount in shows with overt motivational aims; these shows have explicit aims therefore motivational features should be tied to the parts of the show that communicate them. Future research should explore the motivational effects of strategic use and the potentially distracting effect of non-strategic use.

For subtly motivational shows that primarily aim to entertain – to provide a positive science experience for the audience such as a family show in a shopping mall – this question is more complex. My belief is that science shows should be first of all about science. Hence the motivational features should be used to enhance the science, inspire people to think about it more, and provoke them to see the science's relevance to their lives. If science show performers are routinely using motivational features solely, for example, to get a laugh, it may be at the expense of effective science communication. Presenters must be conscious of getting a laugh that furthers the communication of the science. The more central the laugh (or other motivational feature) is to the science – that is, the more endogenous the motivational feature – the better.

An example of strategic use comes from the *Ballistics* show studied in this thesis. In the show a vacuum cleaner is converted in a projectile launcher – a 'vacuum cleaner

bazooka' – while exploring the science of pressure and Newton's first law. I found you could use the bazooka to 'suck' the head off an action figure (dolly) and fire it across a room. Comments on surveys showed this was particularly memorable – the experience was packed with motivational features such as humour, interest and enjoyment. Initially, I did this purely for those reasons – because it was fun – but reflection while working on this thesis showed me I needed to use this powerful experience to convey the science. I now use the decapitated dolly to reinforce the science in a novel and memorable way and I hope make people view their vacuum cleaner in a different light. Moreover, the scientific concepts conveyed by the demonstration – i.e. the head comes off due to pressure and flies in accordance with Newton's first law – are also key ideas in the show. This is a trivial, but illustrative, example of strategic use. Although testing the effects of strategic versus nonstrategic use is a subject for future research, some research hints at outcomes. For example, Schechter, Priedeman and Goodman (2010) observed the most learning from a science show occurred in parts that were enhanced via a motivational feature (interactivity in their research).

Science show presenters are not alone in nonstrategic use of motivational features. One study found only 30% of a teacher's humour was related to course content (Gorham & Christophel, 1990). Non-content related humour can still have beneficial effects on classroom environment and teacher rapport; the same study found use of humorous anecdotes not related to course content had positive effects on attitudes to the teacher, content and behavioural intent (affective learning; ibid.). Hence, in a show the correct balance of non-content related humour or other motivational features may depend on the proportion of overt and subtle (or cognitive and affective) outcomes desired. This raises a difficult issue for show presenters, in that they rarely have one

sole aim for everyone in the audience, although for overtly motivational shows (e.g. the HIV show in this thesis) there are often overriding aims. Accordingly, superfluous yet engaging parts of the HIV show (usually using humour) were discarded during development as they did not convey the key aim of minimising HIV risk. Finding where this balance lies – that is, possible detrimental effects of nonstrategic use – is an important question for future research.

In conclusion, building on similar ideas about use of motivational-triggers in formal learning (Cordova & Lepper, 1996; Malone & Lepper, 1987), it is proposed that the more targeted the motivational feature is to the content communicating key outcomes, the more motivational impact the feature can have. Another way to look at this is the *overlap* of motivational feature and content. If there is no overlap, e.g. humour is used but has no link to desired outcomes, it is possible the feature will actually detract from desired outcomes. Moreover, if the feature is endogenous to the message's communication – a fundamental part rather than an embellishment – this will further enhance impacts. While this seems obvious, science shows (other ISL experiences and formal learning) regularly use motivational features haphazardly, possibly to the detriment of overall desired outcomes.

7.2.2. Know your audience

Although knowing your audience is a fundamental aspect of any effective communication, its relation to the motivational features in this thesis makes it particularly relevant. Analysis showed that both surprise and value had strong relationships with PEPK – one measure of the audience's characteristics. Moreover, variables like pre-motivation and value – both highly dependent on the audience's background – were strong predictors of motivation. So to effectively use these

features, a presenter must know their audience. Later sections will discuss using specific motivational features with specific audience groups, which further reinforces the importance of knowing one's audience. This overarching issue will be returned to throughout this chapter.

7.2.3. Value

Of all the motivational features investigated that show presenters can manipulate, value most consistently predicted motivation – both overt and subtle. While a plethora of literature from both formal and informal learning cites value as a key motivator and important feature, its importance relative to other motivational variables has been little explored. This research suggests that highlighting value is of upmost importance and its motivational effects are stronger than other features investigated, including the other components of SI – emotion (interest and enjoyment) and knowledge. This finding is consistent with the work of Hidi and Renninger (2006) and Linnenbrink-Garcia and colleagues (2010) who claim that value is a, if not the, key catalyst of interest development as it is an endpoint for other influencing factors (see section 2.3.3.). The strong value-motivation association found in this thesis also builds on research suggesting that value is part of sustained-SI (e.g. Mitchell, 1993) – longer-term SI that feeds into ongoing motivation and individual interest.

Findings here are at odds with previous research on components of SI, in which value did not predict changes in individual interest when compared to emotion (Linnenbrink-Garcia et al., 2010). Given individual interest describes a person's enduring disposition to engage with a topic, and motivation describes that engagement, the two have similarities. The research presented here suggests, contrarily, that value is a stronger predictor of motivation than emotion (termed interest-enjoyment in this research).

Linnenbrink-Garcia and colleagues suggest the role of value may be domain specific; indeed, their research investigated mathematics learning which often suffers from a lack of perceived value and failure to be placed in relevant real-world contexts. If the mathematics teaching studied by Linnenbrink-Garcia and colleagues failed to highlight value, this could explain why value failed to influence individual interest (or motivation). The findings presented here suggest that in the domain of science and the medium of science shows, value is of upmost importance for motivation. Given these authors' suggestion of the domain specificity of value, and its overwhelming impact on the ISL settings studied here, research investigating how people perceive value in science should be a priority for future research – as discussed further later.

Findings presented here on the interrelatedness of value with other motivational features, in addition to those in SI models, are also an area for future research. As noted in section 6.7.5., regression results show relationships between value and all other features except surprise. Surprise was the only other variable with this degree of interrelatedness. The nature of value means these relationships are most likely reciprocal, e.g. people are more curious about things they value, and perceive higher value in things they are curious about. These two factors could set up a positive feedback loop where both motivational features are enhanced; in effect value amplifies the other motivational features. Given value was such a strong motivator across the studies, and is widely interrelated with other features, research to better understand these dynamics may enhance the use of all features.

Levels of value

Literature on value suggests that its motivational impacts become greater the more personal and specific it is to the individual. Three levels of value that build on each

other were identified in the literature review. The least personal level of value is simply placing science in a real-world context (level 1), followed by placing it in a context likely to appeal to the specific audience and/or demographic(s) (level 2: the typical approach to highlighting value in educational settings). Ultimately, individuals judge value as they put the science in context within their life (level 3). Whatever efforts ISL practitioners use to enhance value will in the end be judged this way. The levels of value are illustrated in Figure 16. The pyramid shape also suggests that as value becomes more specific to the individual, fewer things will be judged as valuable.

Figure 16. The three levels of value showing value becoming more specific to the individual.

These levels of value were reflected in findings in this thesis, where value (in effect level 3 as it is personally judged) was a more consistent and stronger predictor of motivation than the variable realworld (level 1). In essence, as presenters try to facilitate transitions from lower to higher levels of value they are trying to get people to internalise the value: level 1 is not internalised and encompasses the world as a

whole; level 2 uses the idea that because a group perceives value in something, an individual in that group is more likely to; whereas level 3 is fully internalised, personally judged value. There are two ways of approaching enhancing value of a science show, either one finds out about what the audience values and bases content on that, or one highlights how existing content could be valuable to the audience. Both approaches hinge on knowing your audience.

Fundamentally, to highlight value presenters should begin by placing science in real-world contexts. The importance of this first level was illustrated by one participant when asked what was most interesting about a show:

> Integrating scientific laws into life, [because] it makes science live. Great thing to do.

The idea of making science 'live' – as if it were dead otherwise – eloquently captures the effects of linking science shows to everyday life (level 1), but this is only part way to a person's life (level 3). The intermediary second level relies on show writers and presenters knowing their audience. They need to know what is already valuable to audiences, how to relate show content to these things, and/or how to mount arguments for value where it is absent. These are not straightforward aims. While previous research gives broad pointers to what influences perceived value (usefulness, alignment with identity, emotional factors, and negative/cost aspects; Eccles, 1983), there is only rudimentary understanding of how different demographics (ages, genders, etc.) judge science's value and we know almost nothing about the complexities at the individual level. Moreover, efforts to enhance value at level 2 always make a generalisation about the individual based on what is valuable to a group. It is likely the broader the grouping (e.g. by gender) the less accurate this will be

at predicting value at the individual level. Nevertheless, compared to placing science in general real-world contexts, it is a major improvement to target value by selecting contexts likely to appeal to demographic groups.

As shown by the following comment on which demonstration was most interesting, ways people find more personalised value (level 3) are harder to pinpoint:

> Piston engine, [because] *my boys always ask me* about engines.
> This explained it scientifically.

For this person, the demonstration was useful and hence valuable as it had application in the relationship with her or his children. The value judgment was related to identity, in this case being a parent. For a show presenter, this may not be the first thing that comes to mind in trying to make content more valuable – no doubt there are myriad others. Although research in this work establishes that value in general is critical for motivating audiences, and corroborates underlying features such as utility, it has only scratched the surface. The quantitative research conducted here requires subsequent in-depth qualitative research to flesh out examples of how people judge science's value. Future quantitative research should also establish the validly of different aspects of value (e.g. attainment value; Eccles, 1983) in informal settings. Ultimately, to most effectively use value for motivation in ISL and science communication, there is a need for a detailed framework of how value is perceived.

The relative role of knowledge

Imparting knowledge is often considered the highest priority in a learning experience, especially in formal settings. Findings in this work suggest that compared to the other components of SI, knowledge may not be as critical for motivation. Value in particular was a better predictor of motivation than knowledge. Hence, if motivating people is

the aim, practitioners should prioritise aspects that enhance value above those with pedagogical impact, or better still ensure value is endogenous to critical pedagogical features. This latter approach is an example of strategic use, in this case value being used to motivate learning.

Nevertheless, both formal and informal learning providers often focus on what is to be learnt. Data here, however, suggest we should also be looking at what is valuable. This is particularly relevant to informal settings where the aim is rarely exclusively to educate. Formal learning research shows that when value is increased, learning also increases (Hulleman et al., 2010; Hulleman & Harackiewicz, 2009), meaning greater focus on value is likely to lead to more learning anyway. To implement such recommendations, however, we need detailed information on what people find valuable and why, as discussed further below.

A value of science research agenda

This research has confirmed a principal role for value as a motivator in ISL settings, consistent with its effects in formal learning. While literature on value suggests broad ways to highlight it (i.e. usefulness, identity, emotional factors, and negative/cost aspects; Eccles, 1983), and shows that greater impact occurs the more personally specific value is, there is little knowledge on what aspects of science people find valuable and why. This gap in knowledge makes attempts to increase the perceived value of science problematic. A primary recommendation of this research is rigorous investigation of why different types of people find science valuable.

The perception of value is highly reliant on an audience member's prior experiences and knowledge. This was reflected by a strong positive relationship between PEPK and

value. One issue with value is that it is so all encompassing that asking people what they value about science is not straightforward; it is hard to know where to begin in either asking or answering such a question. The relationship between PEPK and value found in this research may be a useful starting point. Research could investigate the overlap between science related PEPK and value and in doing so identify what aspects of people's knowledge and experience of science they view as valuable and why. A retrospective study asking about people's science related PEPK (excluding science professionals or professional knowledge), then asking why they thought they had retained or recalled that PEPK, may go a long way to finding out which parts of science have value. This is a more manageable starting point than asking broadly why science is valuable as it restricts it to aspects intimately associated to the individual – which are the most powerful aspects of value in any case.

Eccles' (1983) dimensions of value may be another method to apply a framework to or section off parts of value to make research more manageable, for example studies could solely look at the utility/usefulness of science. Attainment value and the related aspect of identity may also be useful starting points, especially as the role of different identities (e.g. parental) has been shown to affect motivation and behaviour and linked to long-term learning in ISL settings (Falk, 2006). A logical next step, especially given findings here, would be to build on this with questions of identity's influence on value and in turn motivation from ISL. Identity has also been dealt with extensively in formal learning, including science learning (e.g. Archer et al., 2010), however few of those ideas have been tested in informal settings. As noted in the literature review, value is possibly more critical in free-choice learning than formal learning, making transferring any lessons about value from the latter all the more critical.

In sum, value was the most critical motivational feature investigated as it had widespread effects on motivation, can be manipulated to a degree by show presenters, and may amplify the effects of other motivational features. This suggests it should be widely and strategically employed for creating motivational science shows. The motivational effects of value are consistent with SI and expectancy-value motivational models, however in contrast to some past research value was found to be a better predictor of motivation than interest-enjoyment. Similarly, findings suggest value is more critical than knowledge/learning related factors for motivation – notwithstanding the strategic use of both in tandem. This thesis has identified three levels of value which become increasingly more specific to the individual: (1) placing science in real-world contexts; (2) placing science in real-world contexts that are likely to appeal to the audience demographic; and (3) when the audience member places science in real-world contexts that are personally meaningful for them. Findings here concur with the literature that value's motivational effects are more potent the more specific it is to the individual. While value is crucial for motivation in science shows, we know little about how people perceive value in science. Future research should address this gap; both models of value and associated variables such as PEPK may provide useful starting points.

7.2.4. Surprise

Like value, surprise appears to be more interrelated than the other motivational features, which is consistent with its role described in the literature of working in conjunction with and blending with other emotions and motivational variables. Although it did not have the widespread motivational effect of value, surprise's role in triggering information-seeking behaviours such as interest and curiosity, along with its

role in discrepant events, make it an important motivational feature within a science show – one we know little about. Although the literature and findings in this research suggest surprise triggers subsequent states, the amplifier role suggested by other authors remains a question for future research. In particular, does surprise amplify states unrelated to information-seeking (little explored in this work)? A possible suspect is enjoyment, which in other settings combines with surprise to create delight and satisfaction (Kumar et al., 2001). These are major objectives in many science shows, especially those with subtle outcomes.

Moreover, surprise plays an important role in learning (Charlesworth, 1969), however it appears that very little, if any, research has investigated this recently. Surprise is the actual moment when one is alerted to a lack of explanatory knowledge, so it represents a prime opportunity to impart knowledge. Reviewing the literature, however, reveals very little on how to best use surprise in learning settings. The body of research on cognitive conflict and conceptual change (i.e. Pintrich, Marx, & Boyle, 1993; Sinatra, 2005) – which also deals with schema-discrepancy and schema replacement and revision – may well benefit from greater understanding of the role surprise plays in this process. Future research on surprise should investigate these cognitive aspects.

Findings presented in this thesis suggest surprise is a useful tool both to motivate people and trigger other motivational features, hence its greater use is recommended. That said, surprise, by its very nature, is a variable that must be used strategically – if everything in a show was surprising that may well create a schema to that effect, hence rendering future surprising events less surprising (even though the exact nature of what is surprising is changing). The role of schemas in surprise, especially findings

here that schema-discrepancy is the conduit between surprise and curiosity, suggest techniques for presenters to better use surprise. These are discussed in detail in the next section.

Schema manipulation

Curiosity models from the literature and models proposed in this work (see sections 6.5.5. and 6.7.5.) suggest ways to enhance demonstrations by manipulating features like surprise, PEPK and curiosity. Three techniques are proposed here. Techniques one and two primarily focus on manipulating schemas and highlighting information-gaps, in particular creating schema-discrepancy. Findings in this thesis suggest schema-discrepancy is key to generating curiosity following surprise. Technique three provides suggestions to foster optimum sized information-gaps that should generate maximum curiosity. The recommendations relate primarily to demonstrations that could be classed as discrepant events, however they could be applied more broadly also. These techniques are not revolutionary, indeed variations on them have been used for eons by performers, storytellers and other communicators. Placing them within the theoretical models used here, however, allows more thoughtful manipulation and suggests future research.

One, at the beginning of a demonstration audiences should be asked to make a prediction, which prompts them to access a schema and form an expectation. The prediction activates prior knowledge in a way that basic procedural activities such as making a calculation do not (McCracken, 2009). Making a prediction actively calls up relevant schema that may either be reinforced (constructivist assimilation) or replaced (constructivist accommodation) upon seeing the result, hence is important for cognitive outcomes. The other aspect of making a prediction is that it highlights an

information-gap about the outcome. As pointed out by Lowenstein (see section 3.1.2.), if people are presented with a result that is contrary to their prediction it sharply highlights the gap in their knowledge.

The critical function of a prediction is the potential to create and enhance schema-discrepancy between the schema activated by the prediction and the result of the demonstration. Research on primary school children suggests that the more precise and concrete predictions are, the more schema-discrepancy and hence surprise is created if they are presented with contrary outcomes (Charlesworth, 1964). Hence presenters should ask for precise, detailed and context-bound predictions. Depending on the age and background of the audience, presenters may need to assist with forming realistic concrete predictions, however they should take care not to reveal the result nor take ownership for the prediction away from the audience. Techniques to reinforce ownership, such as voting with hands or telling the person next to you, may help reinforce the prediction.

In sum, technique one uses predictions to activate people's existing schema, which are the starting point for creating schema-discrepancy and highlighting information-gaps. It is similar to an author posing the question 'Who did it?' in the beginning of a murder mystery. While technique one utilises people's existing schema, presenters often want to draw attention to certain ideas, hence creating a particular schema can be advantageous.

Technique two 'implants' a schema through structuring a demonstration in two-parts. To maximise schema-discrepancy and surprise, part one presents content to establish a schema, while part two presents a variation on part one that is discrepant with that schema. Because the presenter can exert control over both the initially created

schema and the schema-discrepant event, there is greater potential for discrepancy compared to when the initially created schema is salient due to a person's predictions. Moreover, part one of the demonstration provides a highly concrete and 'fresh' schema – rather than speculating based on PEPK to form a prediction, the audience member is provided with an actual experience.

Critically, any aspects of the demonstration – both procedure and result – that change between part one and part two should focus people on the key phenomenon to which the presenter wants to draw attention. These contrasting elements draw people's attention to the schema-discrepancy, which according to findings in this work should facilitate curiosity. Importantly, this curiosity is directed towards the key phenomenon due to the contrasting elements. This is an example of strategic use of a motivator, as discussed in the beginning of this chapter. This two-part strategy was employed in demonstrations presented by the researcher, but not elsewhere. This may be one reason why surprise and curiosity were significant predictors of motivation in these studies but few others. It is worth noting this technique was used before beginning this research because it just seemed to 'work', however it is only through this research I have discovered why it was effective. Again, conclusions reached by both research and practice are reassuring.

An example of this two-part demonstration structure was used in *Booming*. In part one, a balloon full of air was held above a candle over a volunteer's head, which pops on contact with the flame. This establishes a schema that balloons pop on contact with a flame. Part two substitutes a balloon filled with air and water, which – counter to the schema set up by part one – does not pop when touching the flame. While many comments noted how surprising this result was, one hinted at the possible effect of

the two-part structure – note the use of 'still' which suggests part one had established a schema:

I'd never thought about it, and I thought it would *still* burst.

The balloon does not pop due to the heat absorbing properties of water – the key idea in the demonstration. Note that only the element that communicates the key idea (i.e. the addition of water and the heat absorbing properties of water) is changed from part one to two. Care should be taken that the counterintuitive result – the inconsistency between the schema from part one and the result from part two – directs attention to the key idea and not elsewhere. That is, schema-discrepancy should be used strategically. (As an aside, to highlight value, this demonstration concludes with a discussion of car radiators which are an everyday application of the same principle (level 1 value) and then asks the audience to think about it on the way home if they came by car or bus (aiming for level 3 value)).

In line with findings that schema-discrepancy links surprise and D-curiosity (see section 6.7.2.), this technique should foster D-curiosity more than interest to make sense of the surprising result. This is advantageous as several authors have argued D-curiosity is a stronger, more determined form of information-seeking (Litman, 2005; Loewenstein, 1994). As Charlesworth (1969) pointed out, surprise may lead to schema modification (assimilation) or schema creation or replacement (accommodation), as discussed in section 2.5.3.. It follows that D-curiosity may be more responsible for accommodation as it serves to fill information-gaps, where no schema is available and hence a new one must be created – in other words, accommodation. Interest or I-curiosity, in contrast, appears to be more involved in assimilation, where existing schemas are modified and there is no profound information-gap. Hence, this two-part technique with results that

clearly clash is more likely to provoke D-curiosity and accommodation – a new schema that explains the counterintuitive result. Importantly, central to this schema is the key idea that was changed to create the clashing schema. Although cognitive learning was not a focus of this research, testing the ideas proposed here around constructivist processes, D-curiosity and interest is a worthwhile avenue for future research.

Technique three uses the role of information-gap size as a 'gatekeeper' to D-curiosity – as proposed in the literature and the model in section 6.5.5.. The key aim for presenters is creating an optimum sized information-gap; not so large it is considered incomprehensible or not even salient, and not so small it is unnoticeable and fails to create tension and intrigue. The size of the information-gap will be determined by the demonstration and the presenter's preliminary explanation, along with audience member characteristics such as PEPK. The finding that D-curiosity is independent of PEPK suggests it is more likely that information given by the presenter plays a bigger role than PEPK in locating boundaries for information-gaps – at least in typical science show audiences.

As suggested by youth and adult contrasts in *Burning Public* and the model in section 6.5.5., the optimum size of a gap may be affected by characteristics such as age that are associated with PEPK and critical thinking skills – things that inform the size and manageability of the gap, respectively. Based on the audience, presenters need to adapt how much preliminary information or 'hints' to provide so that the gap is salient and manageable. This will depend on the demonstration itself, its novelty (i.e. are people likely to have relevant knowledge or experience) and the science that explains it. A rare and baffling demonstration that only makes sense with specialised knowledge will require more hints to create a manageable gap.

Using predictions and two-part demonstrations, as discussed, may also provide ways to incorporate hints and manipulate the size of information-gaps. For example, hints could be provided by giving people a range of possible results and asking them to predict which one will occur, or by giving information relevant to part two of the demonstration while presenting part one. Presenters should avoid providing too many hints or pre-empting the result, as this will diminish surprise and curiosity – as Bragg (1966) noted, make sure the audience is at first puzzled. Audience feedback, especially the characteristic facial expressions of surprise (during the demonstration) and lack of confusion (during the explanation), are indicators that the right balance has been struck.

Other schema manipulation techniques include overemphasising safety precautions or danger, which also establishes a schema. These techniques were used extensively in *Burning Public*. This included a fire safety officer in full safety gear who was prominently introduced at the start of the show. While this approach is first and foremost sensible risk management, it also sets up a schema that the demonstrations are risky and dangerous. This in turn enhances excitement and tension. It may also create an information-gap around risks of something going wrong during the show, while also closing gaps around serious consequences of those risks.

In sum, manipulating schemas to enhance surprise and curiosity is a powerful technique in science shows. Presenters can utilise techniques such as asking for predictions, using two-part demonstration structures, and providing appropriate hints to manipulate schemas, enhance schema-discrepancy, create optimum sized information-gaps and foster curiosity. Performers have evolved these techniques instinctively as they 'just work' with audiences, or they may have experienced their

impact first-hand while watching other shows. Other art forms also utilise schema-discrepancy including theories explaining the appeal of music and humour. The structure of most jokes relies on the body of the joke establishing a schema and the punchline running contrary to it (Kubovy, 2003). Placing science demonstrations in similar theoretical models, as proposed here, should allow more strategic use and enhanced audience reactions. Further research is, however, required to determine to what degree these techniques are effective, whether they work via the methods proposed here, and their exact effects on motivation and learning. Nevertheless, surprise is an important motivational (and potentially cognitive) feature of a science show, particularly to foster curiosity.

7.2.5. D-curiosity

D-curiosity, which aims to resolve information-gaps, is argued on general and neurological grounds to be a stronger form of information-seeking behaviour than interest (Litman, 2005; Loewenstein, 1994). The thesis found mixed results on this assertion depending on audiences, requiring more targeted future research to resolve. Contemporary formal education literature, however, is very much focused on interest. This suggests that within educational research, and possibly reflected in classroom teaching, D-curiosity is an underutilised motivational feature.

One factor that may be driving underuse of D-curiosity is the failure by most researchers and teachers/ISL practitioners to clearly differentiate interest and D-curiosity. If research does not differentiate interest and curiosity – and note that findings in this work suggest the public does perceive the difference – then it makes it problematic to use them in targeted ways. Despite models which differentiate I-curiosity or interest (this terminology may be part of the issue) and D-curiosity, and

discussion amongst educational psychologists about the differences between interest and curiosity (see section 3.1.6.), the two terms are still discussed together without sufficient emphasis on how they are different (i.e. Silvia, 2012). This in turn leads some researchers to conclude 'Modern research usually uses curiosity and interest as synonyms' (Kashdan, Silvia, Lambert, & Fincham, in press; p. 4). These researchers typically view interest as a dimension of curiosity, consistent with I/D models. Kashdan and colleagues (ibid.) reconciled it thus:

> For historical reasons, some research traditions favour curiosity (e.g., the behaviour theory and individual differences literatures), whereas others favour interest (e.g., the emotion psychology and education literatures). Likewise, research often uses curiosity when referring to individual stable differences but interest when referring to momentary states. Differences in usage aside, the underlying state is the same (for a review, see Silvia, 2006, chap. 9), and we use them synonymously throughout this article.

Findings in this thesis disagree with this approach. Factor analyses conducted during scale development and in answering the sub-questions show the general public differentiate interest, which they associate with enjoyment and fun, and curiosity, which they associate with resolving information-gaps. This does not reflect a synonymous view in the sample studied here. This occurred in all studies featuring these variables. The items measuring interest and curiosity were straightforward, simply asking how much of each the audience felt, hence the items they factored out with give an indication of how the public define interest and curiosity. Moreover, regression analyses show interest and curiosity do not predict each other.

Hence, the approach of viewing interest as a subset of curiosity, and especially using the terms as synonyms, is questionable as the public view 'interest' and 'curiosity' as different experiences. Although this conclusion requires future targeted studies to confirm (it was only a one aspect of this research), and may operate differently in other settings, researchers need to heed the differences between interest and curiosity. This is especially important if the research is to translate into practice, where – according to analysis here – the natures of interest and curiosity are distinct in the general public's experience (or at least those that attend science shows). Moreover, results show one uses different tools to make an audience interested (e.g. through presenter qualities; see next section) as compared to curious (e.g. schema-discrepancy). In sum, failure to differentiate interest and curiosity clearly is likely to hinder our use of these motivational features.

D-curiosity is, however, used effectively in educational settings through processes like inquiry learning and use of discrepant events. As demonstrated in this thesis, application of I/D-curiosity models to understand such processes can be beneficial and it is recommended this be more widely employed. The finding that D-curiosity negatively predicted motivation, albeit not at a significant level, in two studies suggests that it needs to be used with care and at appropriate levels for the audience. Future research on D-curiosity should investigate optimum levels and potential negative effects.

The idea of creating information-gaps to generate curiosity has a long tradition in ISL settings highlighted in the 1960s by Sir Lawrence Bragg's (1966) 'detective story' principle and more recently in science shows through the use of a 'dramatic question' to structure the overall show (Kerby, Cantor, Weiland, Babiarz, & Kerby, 2010). The

detective story principle (see section 3.1.1.) and the dramatic question are prime examples of strategic use, where D-curiosity is used to provide structure and draw attention to the overarching idea of the show. Kerby (ibid.) argues the dramatic question's effectiveness and hints at some of the deprivation aspects it induces (italicised):

> This device, known by playwrights as the "dramatic question", sparks curiosity, elicits attention, and motivates the audience to *wrestle with the problems* presented as the play unfolds. A well-crafted dramatic question provides context and *urgency to the many smaller questions* that are posed, answered, and linked together to form the plot. (p. 1024, italics added)

To summarise, D-curiosity is a useful tool for motivation, especially to motivate learning. Some discussions in the literature on interest and curiosity fail to adequately differentiate these two constructs, which may hinder their use in practice. Importantly, the public view curiosity as D-curiosity and distinct from interest, meaning research and practice should also observe these distinctions should they wish to create such states in people. I/D-curiosity theories, as shown in this research, provide a useful framework to ensure distinctions are made and their application in other learning settings is recommended. Show structures that incorporate D-curiosity discussed above appear to be powerful approaches to its use and are recommended, however require future research to be fully understood – this research should utilise I/D-curiosity models. Other ways to elicit D-curiosity within demonstrations hinge on schema-discrepancy, as discussed in the schema manipulation section. More research is required in this area – particularly in the strategic use of D-curiosity to achieve overt

motivational outcomes, creating optimum sized information-gaps, and, related to this, ensuring feelings of deprivation do not have negative impacts on motivation.

7.2.6. Interest-enjoyment and immediacy

Two main conclusions can be drawn regarding interest-enjoyment: (1) its relationship to immediacy, and (2) its motivational effects compared to value and the implications of this on ISL programs.

Immediacy as a source of interest-enjoyment

Human interactions and 'connection' between practitioner and audience are central to many ISL settings, whether a facilitated workshop, an explainer working with an exhibit, or a guided nature experience. A science show is a particularly good example. Findings in this work suggest that qualities of the presenter that build connection – immediacy behaviours – can be directly motivational in youth and also contribute to interest-enjoyment. Hence, immediacy is a tool to make ISL more interesting, enjoyable and motivational. Yet there is little research on this in ISL settings – something that should be addressed in future research. Studies should address the different aspects of immediacy investigated here (humour, presenter enthusiasm and likeability, interaction) along with others, particularly as they relate to subtle motivational outcomes, where according to results here they have the greatest effects.

More broadly, the finding here that immediacy, of all the variables studied, had the strongest relationship with interest-enjoyment has implications for SI models. While teacher enthusiasm has been suggested as a source of SI once previously (Zahorik, 1996), to my knowledge no research aside from that here has followed this up in detail. Given SI models are widely applied to teacher/presenter led learning

experiences, future research should explore the teacher/presenter's influence on SI. Recent research to develop formal learning SI scales has included items about the teacher's qualities (Linnenbrink-Garcia et al., 2010), however scale development and factor analysis in this thesis show immediacy qualities are a separate aspect which is intimately related to interest-enjoyment (or SI-feeling). Measurements of SI in teacher/presenter facilitated environments should consider including immediacy measures.

Section 6.7.4. posited emotional contagion (Hatfield et al., 1994) as an explanation for immediacy's effect on interest-enjoyment – especially presenter qualities like enthusiasm and likeability. Put simply, enthusiastic presenters enjoy and are interested in their show, hence these emotions transfer to the audience. The results suggest the emotions felt and shown by show presenters, expressed as enthusiasm, are linked to the emotional response of the audience. Hence, content and delivery styles presenters find emotionally arousing, or similarly what they find intrinsically motivating, in their shows may provide a guide to what the audience find emotionally arousing and intrinsically motivating.

Although this is stating the obvious about how presenters create shows, it stresses the need for presenters to be genuine in their emotional response and actively manage their emotions in shows without contriving their delivery. This is not easy; convincingly feigning surprise the hundredth time you have seen something is the work of a skilled actor – a field which science shows could learn from, and fertile ground for future research. Motivational states that embody emotions, such as interest and enjoyment's role in intrinsic motivation, may be more practical ways to help presenters exhibit genuine emotional responses that can transfer to the audience. To foster genuine

sustained emotion in presenters, employers like science centres should select intrinsically motivated presenters who do shows first for 'love' and second for money. Moreover, employers should provide working environments to nurture intrinsic motivation, for example by giving autonomy, control and fostering competence and relatedness through training, feedback and effective team environments. These efforts, based on presenter-audience transmission, may be an avenue to increase audience emotional and motivational response.

Interest-enjoyment and value motivate different outcomes

While value predicted motivation in all circumstances regardless of demographics and the type of motivational outcomes, interest-enjoyment primarily predicted motivation in youth when subtle outcomes were measured. Importantly, findings from *Burning Schools* show that interest-enjoyment did not predict overt outcomes such as future study and careers in secondary school students. These findings are relevant to the plentiful ISL programs that largely target: (1) primary schools aiming for subtle outcomes (e.g. more positive views and awareness of science); and (2) secondary schools aiming for overt outcomes (e.g. future study and careers). Most ISL school programs fit into these categories.

Findings suggest that category one programs should place emphasis both on highlighting value and creating interesting, enjoyable content if they want to achieve their aims; they should focus on 'fun' and relevance. Category two programs, however, need to place greater emphasis on highlighting value than interest-enjoyment to achieve overt outcomes. Beta values from *Burning Schools*, which measured study and career motivation, show interest-enjoyment (beta = 0.03) not only fails to significantly predict motivation when compared with other variables, but moreover the small beta

shows an extremely weak association. Taken to their extreme, the implication of this finding is that interest-enjoyment is irrelevant to motivating overt outcomes in secondary students. One must be careful in conclusions like this as it is likely value and interest-enjoyment are interrelated – this is supported by both the literature and relationships found in this work (they significantly predicted each other). Put another way, interest-enjoyment may enhance value, which then motivates people.

Nevertheless, the results strongly suggest that ISL providers aiming to motivate overt outcomes, such as encouraging secondary students to choose science subjects, should prioritise aspects that show science's value above those that show science is fun – though the latter should not be ignored. This conclusion is supported by formal learning research (as reviewed in section 2.3.3.) by Durik, Vida and Eccles (2006) who found interest and enjoyment ('intrinsic value' in their study) and value predicted short term course enrolment, however only value predicted career aspirations. Their study's results are consistent with the overall findings in this thesis: value is more important for motivating overt outcomes when compared to interest-enjoyment. Both interest-enjoyment and value, however, are important for achieving broader outcomes (i.e. subtle motivation in this thesis, or short-term course enrollment in Durik and colleagues' study). Hence, the best compromise is to create shows and ISL experiences that highlight the value of science in interesting and enjoyable ways.

7.3. Tailoring motivational features to audiences

The second set of conclusions and recommendations from this research discuss which motivational features are most suited to particular audience segments, as touched on above. They also suggest future research related to specific audiences. Across the studies, particular features were more effective motivators in certain segments of the

audience. For example, interest-enjoyment and immediacy had greater effects on youth, hence should be utilised to motivate such groups. Most studies, however, only recorded age and gender – these demographic factors affected motivation and are discussed separately below.

Several other characteristics of the group are likely to affect which motivational features are most effective. A subject for future research is identifying additional motivational features that are important in non free-choice settings, such as school excursions/incursions. In this research, these groups had lower R square values suggesting other motivational features are at play. This research did not reach people who are disengaged with science (see section 6.2.), a group who may have very different motivational features or barriers to motivation since they are not motivated to attend shows and other ISL settings in the first place. ISL programs are actively trying to engage this group, for example the Australian Government's *Unlocking Australia's Potential* initiative, yet we know little about what might motivate the science unengaged or actively disengaged. Future research could test features used here on these groups; comparison of R Square values would suggest whether their motivational experience is indeed different. Research to establish how science un/dis-engaged people perceive value in science, or probably lack of value, may also be fruitful given value's key role in motivation. Similarly, future research may benefit from segmenting general audiences by other characteristics – e.g. the value they place on science or their interest in science (e.g. Sweeney Research Pty Ltd, 2012) – or targeted at different demographic groups – e.g. regional and remote dwellers.

A constructive way to approach the issue of motivational features' differing effectiveness on audience segments is to find out about the audience first – as noted,

knowing the audience is crucial for motivating them. Features like pre-motivation could be used advantageously by surveying audiences prior to shows and customising content to address gaps in motivation, as discussed. Value is another variable around which shows could be customised; presenters already do this informally such as by using everyday examples that are relevant to the specific audience. A structured approach to customising shows to enhance value would rely on knowing how different groups perceive value in science, further underscoring the need for research in this area. It may be possible to use demographic characteristics as general indicators of what is valuable (e.g. older teens typically perceive value in content related to sex), however to customise value on a more individual level – where its effects are strongest – is a more complex question for future research. In sum, both value and pre-motivation suggest opportunities to customise shows based on formative audience research. Given the logistics and resources required, this approach may only be advisable for shows with specific and important outcomes (e.g. the HIV show studied here). That said, the powerful motivational impact of value and pre-motivation found in this work suggest such efforts would be worthwhile, though future research should verify this.

Tailoring motivational features to age

Across the studies, specially the analysis of *Burning Public*, different age groups were more motivated by different features. Moreover, findings suggest youth and adults responded to motivational features in distinct ways, such as the model proposed for surprise, curiosity and PEPK (see section 6.5.5.). While some features like value appear to motivate all ages, others were specific. For example, D-curiosity was more motivational with older audiences, while immediacy and interest-enjoyment were

more motivational with younger audiences. Presenters should emphasise the use of motivational features most effective for the age group they are working with. The question of why these features were age specific is an avenue for future research, e.g. testing the hypothesis that D-curiosity better motivates adults because optimum sized information-gaps are created. The vexing question of how to simultaneously motivate mixed age family audiences who appear to have different motivational triggers is also important for future research, since they are a major science show audience.

Across all but one study, older people were less motivated by the shows. Reasons for this have been discussed, however the finding also suggests either that other features may better motivate adults, or that the features investigated become less motivational with age – again, topics for future research. A final note on age regards the underrepresentation of 15-30 year olds in free-choice shows; it is important future research investigates why they are not motivated to attend (along with other disengaged audiences) and what may best motivate outcomes in them if they did attend – including what this age group value. This is a particularly important age group as this is the time when people make decisions on tertiary study and careers.

In sum, age was an influence on which features were motivational and the amount of resulting motivation. Hence presenters should emphasise different motivational features depending on audience age to achieve greater motivational impacts.

Tailoring motivational features for different genders

Section 6.5.8. discussed the role of gender in influencing motivational outcomes. Gender did not have widespread effects, however findings that explosions, fire and other similar content (*Booming* and *Burning Public*) had greater motivational effects on

young males have implications for show designers and presenters. These types of demonstrations are widely used in science shows, particularly in chemistry shows.

Gender difference findings here are consistent with research in physics teaching where aligning content to anecdotally known interests of boys or girls resulted in better learning outcomes and motivation (Hoffmann, 2002). The same study concluded that numerous empirical findings showed girls have lower interest in the 'hard' sciences such as physics and chemistry and trends occur both in and outside school (e.g. in a science show). According to Hoffman, 'girls in particular respond very sensitively to a change of context' (2002; p. 450) and girls find contexts relating to people, biology, social interactions and relationships, and natural phenomena appealing. Importantly, most things that were appealing to girls were also appealing to boys, but not vice-versa (ibid.). Placing content in an appealing real-world context fosters level 2 value, as discussed, and Hoffman's results suggest gender will have an influence on this.

Hence, show presenters should be conscious of the different contexts in which they place show content, especially – as one risks alienating half the audience – in using contexts that appeal to both genders. Hoffman's findings suggest that having female-friendly contexts should be the priority as these will also appeal to males. That said, show content and presentation must be careful not to favour genders unequally. This underscores the importance of gender diversity in presenter teams; male presenters appear to be more in tune with what motivates and appeals to young males (I am instinctively drawn to explosive demonstrations, however it is the exception in my female peers), and I can only guess a similar relationship exists for female presenters. In sum, further research is needed to test the effects of different contexts on males and females, and also the effects of the presenter's gender in influencing contexts

chosen. This research should sit within a wider agenda to establish how people (including those who communicate it) judge value in science, as discussed.

7.4. What about other motivational features?

Across the studies in this thesis, mean R square values showed the motivational features along with demographic factors explained just over half the variance in motivation – so what explains the other half? Several other variables suggest avenues for future research. The new variables could be investigated separately based on methods in this thesis, and then included alongside those studied here to establish if the variance in motivation they predict overlaps (stable R square) or adds to the model's explanatory power (increases R square) – notwithstanding other factors which affect R square such as the show and audience. The way the motivational features were selected in Chapters 2 and 3 suggests several other variables that may be potential motivators during a science show.

This thesis focused on intrinsic motivators, however several were omitted due to being less relevant to science shows. As argued in section 2.2.1., variables such as autonomy and control are components of intrinsic motivation (Deci & Ryan, 1985), but the structured, presenter-led experience of a science show means these aspects are not so relevant to a typical science show. Some innovative show formats, however, do allow the audience more control on what is presented. For example, a 'choose your own adventure' format has been used secondary school shows presented by Questacon – The Australian National Science and Technology Centre, whereby audiences had the option to choose different pre-planned segments of a show. According to intrinsic motivation theory, allowing control and autonomy should enhance intrinsic

motivation. Future research could compare these audience directed formats with traditional shows.

Self-determination theory (Ryan & Deci, 2000), another theory which grew out of intrinsic motivation, also suggests other variables. In self-determination theory, competence, a measure of confidence and self-efficacy, is a source of intrinsic motivation. As a motivational variable, competence has similarities with expectancy in expectancy-value theories. Measures of competence and expectancy were excluded from this research (see section 2.2.1.) as generally the audience is not directly tested and challenged as they watch a show, in comparison to performing a physical task such as in a hands-on workshop. The audience is, however, asked to perform mental tasks during a show. If an audience member is consistently confused during a show, this may decrease competence and expectancy of future understanding, hence reducing overall motivation.

The effects of competence and expectancy described above are particularly related to cognitive aspects of a show (which was not the focus of this research). These variables are hence relevant to shows that aim to educate, but also relate to shows where presenters try to motivate audiences through scientific evidence and arguments. For example, the *Sustainability* shows included arguments for the environmental benefits of ethanol-blended petrol – if people feel they lack competence to understand these, this may well affect motivation to use such fuels. More broadly, this highlights the effect of learning and other cognitive factors on motivation – a broad area for future science show research not dealt with in detail in this thesis. In addition, competence and expectancy may be important when studying certain overt motivations, especially as they relate to actual behaviour. For example, if a young person has never used or

been taught how to use a condom, then competence and expectancy may have major effects on condom use behaviour.

Negative emotions, as excluded from this research in section 2.4.5., may contribute to or detract from motivation, however any future research in this area needs to proceed with caution. One aspect that carries less risk is investigating the role of factors like fear, confusion and other negative states during a normal science show, e.g. what is the motivational effect on an audience member who feels fear rather than excitement during explosive demonstrations? Motivational outcomes from negative states are likely to be specific to certain topics and audiences. Such thoughts were highlighted while performing a show including explosions to a group of orphans in the Middle East, many of whom came from war-torn counties. In these cases, negative states may detract from motivation, however arguments for the converse also exist – such as using fear or guilt to motivate changes in health or environmental behaviour. As noted, one South African colleague suggested using fear to motivate safe HIV behaviour. This area is an ethical minefield, however it does pose potentially important questions for careful future research. Although fear-appeals have been discouraged in climate change communication (O'Neill & Nicholson-Cole, 2009), some people are scared of climate change (or HIV) meaning that these negative states play a role, even if they are not actively used as motivational tools.

As argued in section 6.4.1., the fact that models explained half the variance in motivation and focused on intrinsic motivators suggests extrinsic motivators are worthwhile candidates for future research. Lower R square values in overt motivation studies suggest extrinsic factors may play a greater role in these. Similarly, lower R Square combined with lower beta values for value in *Burning Schools* suggest other

features, quite possibly extrinsic motivators, play a greater role in further study and career motivation. A wide body of literature addresses both extrinsic motivation and study and career motivation, however was not utilised in this thesis. The motivational effects of these extrinsic motivators during science shows should be investigated in future research.

Finally, the nature of a science show experience suggests several other potential motivational features for future research. These include social interaction and circumstances of audience members (e.g. the dynamics in a family group), the context and location the show, and the types of demonstrations and props used (and probably many more). Demonstration types is an exciting area for future research as this has already been shown to affect recall (Sadler, 2004) and may integrate with research presented in this thesis. As discussed earlier, some motivational features studied here are endogenous (a central part) to certain demonstration types. For example, surprise and D-curiosity are endogenous to discrepant events, and interaction and involvement are endogenous to demonstrations using volunteers and Gedanken thought experiments. How these endogenous motivational features and demonstration types affect each other is an intriguing question. Moreover, questions like what is the most effective way to make value endogenous to a demonstration may yield potent motivational tools. The use of everyday items and contexts as major aspects of demonstrations may make value endogenous, as may incorporating specific knowledge of the audience – these are exciting areas for future research.

In sum, numerous variables warrant future research to establish if they are additional motivational features of science shows. These include intrinsic motivators not studied here such as autonomy, control, competence and expectancy, cognitive and learning

related factors, extrinsic motivators, negative states, and aspects of the show itself, particularly demonstrations. These variables may have relationships to those studied here. Future research should address these issues, particularly for shows aiming for overt motivational outcomes such as inspiring further study and careers.

7.5. Limitations

The implementation of this research encountered a number of limitations, in addition to those outlined in the Methods chapter. These can be divided into limitations of the final samples, survey performance and measurement issues, appraisal-based measurement of emotions, and overall limitations.

As discussed in section 6.2., the sample that attended the shows was not representative of the general public. Audiences in free-choice public shows were most likely science engaged, hence results may not be generalisable to the wider public, especially the science disengaged. Moreover, most public audiences – apart from *Burning Public* – were comprised of almost entirely family groups, hence overall results are not representative of the motivational experience of all individuals, especially older teenagers and young adults who were underrepresented. Apart from in *HIV*, all audiences were from Canberra, Australia – an area with higher educational attainment than elsewhere in Australia (Australian Bureau Of Statistics, 2010) – which may affect their attitudes to free-choice learning and understanding of the show. In some studies, such as *Sustainability 2010* and especially *2011*, sample sizes were less than ideal for regression analyses of motivation and factor analysis during scale development. Implications of this have been discussed earlier.

Administering the survey instruments encountered several limitations. As expected, a small proportion of participants failed to finish surveys in all studies, however this was a larger issue in *Sustainability 2011* where almost half the audience failed to complete the second page of the survey. On the other end of the spectrum, a minority also completed surveys before shows were finished, meaning they were distracted and answers were not representative of the whole show. A small proportion of participants lodged 'dummy responses', for example ticking the same response on a Likert scale for all items in the survey (note these surveys were discarded). Dynamics in the family audience often meant parents would assist younger children to complete surveys, possibly influencing responses. Problems with inappropriate vocabulary for very young children were also observed. Vocabulary and English language competency were a major problem in *HIV,* however the complexities and possible error introduced by a back-translation methodology outweighed problems encountered so was not pursued. In sum, a range of issues around how participants completed surveys may have influenced the quality of the data.

The approach of using appraisals or underlying components to deepen the measurement of emotions and curiosity was successful for some features, but had limitations with others. Surprise and curiosity performed well, forming discrete factors comprising the appraisal or underlying component items along with items referring to the state itself. This approach yielded important insights such how schema-discrepancy linked between surprise and curiosity.

For interest and enjoyment, however, appraisal based approaches were sometimes untidy, with appraisals not always forming factors with their associated emotions, or co-loading across several factors. Interest's appraisal of coping potential was

problematic, for example in *Booming* an item measuring understanding failed to form a factor with interest, although in *Going Ballistics* an item measuring if content was at the right level had more success. Moreover, semantic difference scales based on earlier appraisal work on interest (Silvia, 2005b) proved unsuitable for this research, probably due to the younger demographic and English language competence of the audience in *HIV* where they were trialed. Although appraisal approaches to interest and enjoyment measurement worked better in some studies, there were still issues. Hence it was decided early in the data collection to create a composite interest-enjoyment measure that had higher reliability, could be compared across studies (except *Sustainability 2011* which used the DES), and fitted SI models that combine these two constructs.

Nevertheless, the initial intention of this research was to measure interest and enjoyment separately. These issues meant measurement of interest and enjoyment individually was stifled, making relative effects on motivation problematic to determine. Future research investigating these emotions may be better off using DES measures, which should be tested more broadly in ISL settings – most critically where emotions are used as indicators of learning (e.g. the Generic Learning Outcomes used in the United Kingdom; see section 2.4.7.). In sum, while the appraisal based approach deepened measurement and yielded insights, it was more effective for some motivational features than others.

The nature of the research, which measured numerous related emotions and states simultaneously, probably added to these limitations. In essence, the more closely variables are associated, the more difficult it is to obtain sharp contrasts between them. Given all variables were related to motivation, co-loading sometimes occurred

between motivational features and motivational outcomes. In most cases, and especially if the co-loading also had a conceptual basis (e.g. between curiosity items and information-seeking motivation items), these items were dropped. This reduced scale reliabilities, however not to an inadequate level.

The fact that this research was exploratory and the novel science show medium meant most items and scales had to be developed from scratch. Limited human resources and time to complete the project meant that, while best efforts were made, scale development procedures were not perfect. Space on surveys was also limited, meaning some scales only contained two or three items. This probably affected the small number of scales which had less than desirable reliability, and hence slightly lessen the reliability of overall conclusions. Nevertheless, reliabilities steadily increased through the studies as scales were refined.

A final but significant limitation, as touched on throughout this thesis, is that this research only took a snapshot of motivation immediately after or motivation change before and after the shows. It is unknown if this short-term measure is indicative of sustained motivation, if the motivation flowed through into effects on behaviour, or what factors after the show or which audience characteristics influence such effects. This is the most critical question for future research on the motivational impacts of science shows. Another implication of the short-term measures of motivation is that literatures that look at longer-term aspects of motivation, for example that on behaviour change or social marketing, were not used in any depth in this work. Knowledge from these fields should underpin future research.

7.6. Précis of recommendations

Numerous recommendations have been discussed throughout this chapter. Key points have been synthesised below.

7.6.1. Précis of recommendations for practice

This thesis contains many insights for how best to use the motivational features, however a few key aspects should be highlighted. The motivational features should be used strategically to enhance communication of key messages. This is critical in shows with overt aims where nonstrategic use should be avoided, or if used its impacts – positive and/or negative – should be researched. Surprise and curiosity should be enhanced through schema-manipulation techniques, including asking for audience predictions, using two-part demonstration structures and creating optimum sized information-gaps. Similarly, show structures that use D-curiosity as a template, such as a 'dramatic question', should be explored and researched. Presenters should increase perceptions of value by placing science in real-world contexts that are appealing to specific audiences, in particular different genders. When using the motivational features, presenters should aim to genuinely embody them – believe in the value inherent in the science, exhibit the emotions a demonstration provokes, and convincingly express the motivation and inspiration they gain from a scientific message. Personifying such things as a presenter should facilitate the same in audiences.

Many of the recommendations above rely on presenters knowing their audience. Presenters should use motivational features most effective for particular groups, e.g. interest-enjoyment and immediacy for youth, and D-curiosity for adults. More structured ways of 'knowing' the audience should be used for shows with critical overt

aims, including customising shows based on formative research of audience pre-motivation and value. Research should test the efficacy of this approach.

Presenters and those managing show and other ISL programs should clearly establish their motivational aims, then ensure the most effective motivational features for these aims are used. Programs aiming for subtle outcomes (e.g. positive views of science), especially in youth, should consider interest, enjoyment, immediacy and value. In programs aiming for overt outcomes (e.g. future study or specific behaviours) value should be the primary focus. Moreover, for settings chiefly aiming to inspire and motivate, enhancing value should be prioritised above, or overlapped with, pedagogical features.

7.6.2. Précis of areas for future research

The most pressing area for future science show research is to investigate the long-term motivational effects of science shows, including how the show and other factors affect the transition of motivation into behavior and behavior change. This research should build on existing literature and behavior change models, as well as the findings here.

The motivational features investigated in this thesis provide numerous avenues for future research. One general aspect is to determine which specific elements of the show people associate with the motivational features. Another overarching point is to test recommendations made here on strategic use, e.g. how does nonstrategic use of motivational features affect motivation (or other outcomes), and what balance of strategic versus nonstrategic use best achieves different aims? The DES emotion measures require further testing in ISL settings; they should also be assessed for measuring emotions where they are used as learning indicators (see section 2.4.7.). As

subtle motivation and attitudinal changes in youth are probably the most common aims for ISL, research should further explore the influence of immediacy in this, and how it interacts with interest and enjoyment. SI models used in human facilitated settings (e.g. workshops, shows and classrooms) should also better incorporate immediacy.

Research on value, a potent motivator, should be a high priority – not just for science shows and ISL, but for science communication broadly. It should determine how people perceive value or lack thereof in science, and how this operates in demographic groups. The way value transits from the general real-world (level 1) to the specific personal-world (level 3) should be explored. Research should investigate how value and surprise interact with other features and potentially amplify them. Constructs such as PEPK and dimensions of value (e.g. utility, identity) may be useful entry points for this research.

Future research should test the usefulness of applying I/D-curiosity models more widely to understand learning settings. This research should use focused methods to test assertions that D-curiosity is a stronger form of information-seeking behaviour than I-curiosity (interest). It should explore how to create optimum sized information-gaps and the potential negative motivational effects if they are too large, or of D-curiosity in general. Research should test the schema manipulation techniques and validate related models proposed in this thesis. The role of surprise and D-curiosity in cognitive outcomes, especially in constructivist learning models, should be explored. When investigating interest and curiosity, researchers and practitioners should take care to distinguish the two, as they have different triggers and are distinct experiences.

A final area for future research is establishing additional motivational features in science shows and ISL settings. Likely candidates include other intrinsic motivators (autonomy, control, competence and expectancy), cognitive/knowledge aspects, negative emotions (with care), extrinsic motivators (particularly for further study/careers and other overt outcomes) and social context. Motivational features for certain demographics are less understood – particularly school groups or other non free-choice settings, those disengaged with science, 15-30 year olds, and adults – so should be considered in future research. The motivational and cognitive effects and mechanisms of different demonstration types, including the role of the motivational features studied here in them, is another rich avenue for science show research.

7.7. Overall implications of this research

Science shows are effective motivational tools. Findings in this thesis contribute substantially to the small body of literature on science shows, in particular with regard to their motivational impact which has not been studied in any depth previously. Moreover, findings show that intrinsic motivators are associated with about half of the motivational outcomes from ISL experiences like shows, building on previous research that argues they also motivate attendance (e.g. Csikszentmihalyi & Hermanson, 1999). These findings should provide confidence to organisations and presenters involved in delivering science shows – their shows do inspire and motivate. Findings here, however, do not show if these effects are sustained, although are a positive sign. Science shows are effective at influencing subtle forms of motivation, such as improving people's attitudes to science, which is reassuring given the vast majority of science shows aim for such outcomes. Organisations should continue using science shows for these purposes.

The finding that science shows can also influence overt forms of motivation, i.e. influence specific behavioural intentions, has wider implications. No research has addressed this issue. This research shows that science shows can be used to address socioscientific issues like HIV AIDS and climate change. Very few science shows, however, actually attempt to influence behavioural intentions related to health and the environment, as studied here. This research suggests that organisations like science centres, which regularly have exhibitions related to socioscientific issues, should also include shows in their programming.

A deeper implication is the potential moral obligation that ISL organisations (e.g. science centres) providing science shows have to their communities. That is, if communities face socioscientific problems, and a role of ISL organisations is to engage those communities with science, are such organisations obligated to use tools like science shows to help – especially given this thesis shows they can help address the problems? This thesis cannot answer this question in every circumstance, but recommends ISL providers give it serious consideration based on their local issues. The general answer in my opinion, however, is yes. If ISL providers have tools like science shows that can address community problems, they should use them. Hopefully advantages of science shows – e.g. low costs, portability, minimal staff resources, and rapid development time – as compared to other media like exhibitions will encourage more ISL providers to consider using shows to tackle social problems where science plays a role.

In complex issues such as climate change, questions of balance, objectivity and lack of bias in communication are important in any efforts to motivate people. Although ISL providers may have many competing influences (i.e. funders, policy makers and special

interest groups) in this regard, ultimately they need to *stay true to the science* when deciding how issues should be communicated and which behaviours are appropriate to try and motivate.

In sum, science shows can motivate people. It is up to providers to use them strategically for the greater good.

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Appendix A: scale items

The following section lists all scale items. If scale characteristics were critical to broader interpretation of results these issues are also discussed within the body of the thesis. Where relevant, details from the factor analyses used to guide scale development are noted beneath each scale. Where scales are the same or similar to earlier studies, only the item wordings sans explanatory notes are included.

As described in details in the Methods chapter, most scales include items noting the emotions or motivational variables directly (e.g. including 'interesting' or 'curious'), along with their underlying components (appraisals or other components).

Scale items: Booming

INTEREST-ENJOYMENT

1. The show was a good thing to come to
2. It was easy to pay attention to the show
3. I thought the show was interesting
4. I enjoyed the show
5. I thought the show was fun

In all but one study where emotions were measured using the Differential Emotions Scale, interest and enjoyment formed a single factor. Given this, and that many theoretical models (e.g. SI, intrinsic value and the emotional component of intrinsic motivation) combine interest and enjoyment, they were combined into a single interest-enjoyment scale.

Two items measuring happiness from the show and excitement about coming to the show co-loaded or loaded onto the motivation factor, hence were dropped. As discussed in the Methods chapter (section 4.7.2.) any co-loading of items between

independent (motivational features) and dependent (motivation) variables will artificially inflate beta coefficients. Two items measuring understanding/coping potential (an appraisal of interest) were also dropped as they did not form a single unidimensional factor. A reverse scored item measuring how boring the show was dropped as it lowered reliability.

MOTIVATION

1. I will think about the show after I leave today
2. I will try to find out more about some things in the show
3. I would like to see more shows like this
4. The show made me want to discover more about science

Factor analysis showed the motivation scale items had no co-loading, in particular between the information-seeking items above (one, two) and the items in the curiosity scale.

IMMEDIACY

1. I liked it when audience members volunteered
2. I liked when the presenter made me feel part of the show
3. Seeing the experiments made me feel involved in the show

This early immediacy scale focused on involvement and interaction only.

SURPRISE-CURIOSITY

1. I was surprised by some of the experiments
2. The show had some things I had never seen before
3. I was curious about what would happen in the experiments
4. The show made me wonder about some things I saw

Factor analysis showed items measuring surprise and curiosity formed a discrete factor, hence they were combined. A surprise-item measuring amazement was dropped as it co-loaded on the motivation factor.

VALUE

1. I saw that parts of the show related to my life
2. The show helped me understand things in the world
3. The things I learnt were important to me

Item three had minor co-loading on the motivation factor, but higher loading on the value factor. After reviewing item wording to ensure item three was conceptually distinct to motivation, and given the value scale only had three items, it was decided to retain the item despite co-loading.

Scale items: QVC

In general, the factor structure of *QVC* items was less clear than other studies. While items did form meaningful factors, there was less clarity between the motivational features with some co-loading. It is possible the young sample differentiate less between variables. Importantly, the motivation factor was discrete and after dropping three items had no co-loading on other factors.

CURIOSITY

1. There are things I am still wondering about now the show has finished
2. The show made me very curious
3. I still have questions about what we saw in the back of my mind

In contrast to *Booming*'s curiosity scale, *QVC*'s contained two items directly relating to D-curiosity and information-gaps.

HANDSON

1. There were lots of activities for us to do in the classroom
2. The show had hands-on activities for us to do

During discussions with show coordinators, I was lead to believe many shows would incorporate in-school activities facilitated via the video link, however this was not the case in the final shows studied.

IMMEDIACY

1. We were able to talk to the presenters easily
2. There was good interaction with the audience
3. I really liked the presenters
4. It felt like the presenters were actually in the room
5. The presenters were very enthusiastic
6. The presenters made us feel part of the show
7. The show was funny

This immediacy scale contained a high proportion of involvement and interaction items, which are sustained-SI or 'hold' features that lead to longer term SI. It also had items specific to the video-conference format (one, four).

INTEREST-ENJOYMENT

1. The show was interesting
2. I enjoyed the show a lot
3. I had fun for the entire show
4. The information was about the right level for me
5. I was able to understand everything in the show

Efforts were made to reduce ceiling effects by wording items at the extreme, for example use of 'a lot' in item two and 'the whole show' in item three. The scale also contained two understanding/coping potential items (four, five).

MOTIVATION

1. The show encouraged me to keep studying science at high school
2. I'm lots more excited about science now than before the show
3. I will try to find out more about things in the show
4. I like science more now that I've seen the show

As noted, motivation items formed a discrete factor. There was no co-loading between the information-seeking item three and the curiosity scale. Three items (being inspired, wanting to discover more about science, and thinking more about the show) were dropped as they showed low-magnitude (approximately 0.35) co-loading on other factors.

REALWORLD

1. The show helped me understand things in everyday life
2. I could see how the show related to things in the outside world

This scale is a essentially a stripped back value scale, using only items that relate the show to everyday life, rather than the specific lives of students and what is relevant/valuable to them.

SURPRISE

1. Some things I learnt were different to what I had thought before
2. I was surprised by some of the experiments
3. Sometimes experiments turned out differently to what I thought

This surprise scale focused more on schema-discrepancy than earlier versions.

Scale items: Ballistics

CURIOSITY

1. Curiosity was something I felt during the show
2. I still have questions about what we saw in the back of my mind
3. There are things I am still wondering about now the show has finished
4. Some things in the show made me very curious

IMMEDIACY

1. There was good interaction with the audience
2. I really liked the presenter
3. Jokes and humour made the show better
4. The presenter was very enthusiastic
5. The presenter made us feel part of the show
6. I really liked when audience members volunteered
7. The show was funny

INTEREST-ENJOYMENT

1. I had fun for the entire show
2. The show was interesting
3. I enjoyed the show
4. I was interested in the show from start to finish
5. I thought the show was a good thing to come to
6. The information was about the right level for me
7. The show was exactly what I was hoping to see

This scale contained one interest appraisal for coping potential (6) and two enjoyment appraisals for goal satisfaction (5,7).

MOTIVATION

1. The show made me want to discover more about science
2. I will think more about the show after I leave
3. I will try to find out more about things in the show
4. I feel really inspired after seeing the show
5. I still think science is **not** really for me
6. Seeing the show gave me a more positive view of science

An item measuring being more excited about science after the show was dropped due to cross-loading on the surprise factor.

REALWORLD

1. The show helped me understand things in everyday life
2. I could see how the show related to things in the outside world

SURPRISE

1. Some things were really unexpected
2. I was surprised by some of the experiments
3. Sometimes experiments turned out differently to what I thought
4. Most stuff in the show was new to me

Scale items: Burning Public

CURIOSITY

1. The show made me curious
2. There are things I am still wondering about now the show has finished
3. I still have questions about what we saw in the back of my mind
4.

IMMEDIACY

1. The show was funny
2. There was good interaction with the audience
3. I really liked the presenter
4. The presenter was very enthusiastic
5. The presenter made us feel part of the show
6. Jokes and humour made the show better

INTEREST-ENJOYMENT

1. I had fun for the entire show
2. The show was interesting
3. I enjoyed the show

MOTIVATION

1. The show made me want to discover more about chemistry
2. I feel really inspired after seeing the show
3. I'm a lot more excited about chemistry now than before the show
4. Seeing the show gave me a more positive view of chemistry
5. I'm more interested in chemistry now than before

Three items, two that measured further thought/information-seeking and one measuring an aversion to chemistry (reverse scored), were dropped from this scale as they co-loaded on the value and/or curiosity factors. One other information-seeking item (wanting to discover more) co-loaded on the value factor; this items was retained as it was conceptually quite distinct – though this does highlight the value – information-seeking relationship.

PEPK

1. I already knew some stuff we learnt in the show
2. Parts of the show reminded me of things I've seen or done

This was the first study to investigate prior knowledge (item one) and prior experience (item two).

SURPRISE

1. Sometimes experiments turned out differently to what I thought
2. I was surprised by the show
3. Some results were really unexpected

'Most stuff in the show was new to me' was dropped from the surprise scale as it showed a high inverse co-loading on the PEPK factor. Inclusion of this item in either scale substantially changed regression results as well as compromised the unidimensionality of the scales, hence it was omitted entirely. The co-loading does

however support the relationship of PEPK (schemas) to what is surprising – essentially the PEPK and familiarity of show content is inversely related to what is surprising.

VALUE

1. I could see how the show related to things in the outside world
2. The show was relevant to my life
3. The information in the show was important to me
4. There were things in the show I have a personal interest in
5. The show helped me understand things in everyday life
6. The show had ideas that I can use myself

This was the first study to use a full value scale, which measured both general links to everyday life and specific relevance and value to the individual. The concept of usefulness, that content was valuable as it had direct application for the individual (utility-value), was also included.

Scale items: Burning Schools

IMMEDIACY

1. The show was funny
2. There was good interaction with the audience
3. I really liked the presenter
4. The presenter was very enthusiastic
5. The presenter made us feel part of the show

INTEREST-ENJOYMENT

1. I was able to understand everything in the show
2. The information was about the right level for me
3. I could see how ideas in the show linked together
4. The show was interesting
5. I enjoyed the show
6. I had fun for the entire show

Items 1-3 measured coping potential/understanding (interest appraisal) of the show. Provisional regression analyses showed that beta values were approximately equivalent and non-significant whether a shorter three item interest-enjoyment scale (just items 4-6) or this full six item scale was used.

MOTIVATION (pre, post and change)

1. I'm really interested in chemistry
2. I'd be willing to learn more about chemistry in my spare time
3. I would like to study chemistry at university
4. I think chemistry is boring*
5. I want to learn more about chemistry
6. I think scientists using chemistry have a great job
7. Chemistry can be a lot of fun
8. I would like to find out more about chemistry careers
9. I find chemistry really inspiring
10. I will work really hard at chemistry at school
11. I think chemistry would be an exciting career
12. I will choose chemistry when I get to make subject choices
13. Chemistry is not something I'd consider doing as job*

* Items were reverse scored. Items were measured pre and post creating a pre-motivation and motivation-change score.

PEP

1. I already knew some stuff we learnt in the show
2. Parts of the show reminded me of things I've seen or done

SURPRISE-CURIOSITY

1. I still have questions about what we saw in the back of my mind
2. There are things I am still wondering about now the show has finished
3. The show made me curious
4. I was surprised by some of the experiments

As with *Booming*, surprise and curiosity formed a discrete factor and hence were combined.

VALUE

1. I could see how the show related to things in the outside world
2. The show was relevant to my life
3. The show had ideas that I can use myself
4. The information in the show was important to me
5. There were things in the show I have a personal interest in
6. The show helped me understand things in everyday life

Scale items: HIV

MOTIVATION

1. I want to learn more about HIV and AIDS
2. I plan not to have sex until I am older
3. I am worried about catching *HIV*
4. I will be faithful to one partner, If I do have sex
5. I will always use a condom, If I do have sex
6. I think I can stay completely safe from *HIV* AIDS
7. I will talk about *HIV* AIDS with my friends
8. ABC (Abstain, Be faithful, Condomise) is the way I choose to live my life
9. It is OK to have unprotected sex sometimes
10. At the moment abstinence is the best choice for me
11. I will have an *HIV* test if I do something unsafe
12. I will try hard to find new information on *HIV* AIDS
13. I will talk about *HIV* AIDS with my family
14. I am sure I can behave in ways that keep me safe from *HIV*
15. I will do ABC (Abstain, Be faithful, Condomise) even if other learners do not do ABC

Items were measured pre and post creating a pre-motivation and motivation-change score. The scale included a range of HIV related behaviours, or influences on behavior, derived from the literature and experience with the target group. Language consistent with the South African setting (i.e. 'ABC') was used.

INTEREST-ENJOYMENT

1. I was interested in the show
2. I could understand the information in the show
3. I enjoyed seeing the show
4. Overall, I liked the show

A reverse scored item measuring boredom and an interest appraisal item measuring complexity were dropped as they did not group with other items in a discrete factor. Item two measuring interest's appraisal of understanding/coping potential did however factor together with the other items and was retained.

Knowledge items

1. I learnt a lot about HIV AIDS from the show
2. I am sure I know all the ways a person can get HIV*

* Item was measured pre and post creating prior knowledge of transmission methods and change in knowledge of transmission methods scores.

Scale items: Sustainability 2010

MOTIVATION

1. I will think more carefully about things I do that affect the environment
2. I'm more likely to choose ethanol petrol or suggest it to the person filling up
3. I will do more to encourage others to behave in ways that are good for the planet
4. I'll make some decisions differently when it comes to environmental things
5. I feel more confident I will behave in ways that help the planet
6. I will talk to all kinds of people about the things I learnt today
7. I will try harder to recycle everything I can

Note motivation wording, although only measured after the show, was written to capture change from show. Specific behaviours/motivations mentioned, such as ethanol petrol and recycling, related to show content.

INTEREST-ENJOYMENT

1. The show was interesting
2. I had fun for the entire show
3. I enjoyed the show

In previous studies, these three items consistently showed high loadings onto the interest-enjoyment factor, so were used as the scale items (no appraisals were measured).

KNOWLEDGE

1. I didn't know the benefits of using ethanol in petrol
2. It surprised me how much energy you save by recycling

Despite a post-only study, the wording above was designed to measure change in knowledge from the show through asking whether information in the show was new to the person.

IMMEDIACY

1. The show was funny
2. There was good interaction with the audience
3. I really liked the presenter
4. Jokes and humour made the show better
5. The presenter was very enthusiastic
6. The presenter made us feel part of the show
7. I really liked when audience members volunteered

VALUE

1. I could see how the show related to things in the outside world
2. The show was relevant to my life
3. The show had ideas that I can use myself
4. I think the information in the show was important
5. There were things in the show I have a personal interest in
6. The show helped me understand things in everyday life

CURIOSITY

1. I still have questions about what we saw in the back of my mind
2. The show made me curious
3. There are things I am still wondering about now the show has finished

Scale items: Sustainability 2011

IMMEDIACY

1. The show was funny
2. The presenter made us feel part of the show
3. There was good interaction with the audience
4. The presenter was very enthusiastic

This was a stripped down version of the immediacy scale, again using items that had a high factor loading in previous studies while ensuring a range of items measuring different aspects of immediacy were retained.

KNOWLEDGE

1. Solar and wind power create energy without making climate change worse
2. Petrol with ethanol in it is better for the environment than regular petrol
3. Recycling saves a huge amount of energy
4. I understand why different actions are good or bad for climate change
5. People's individual actions can make a difference when it comes to climate change

Items were measured pre and post creating a pre-knowledge and knowledge-change score. These knowledge items were conceptually related to motivation items to see if knowledge of the benefits a particular behaviour influenced motivation. Specific topics dealt with such as recycling formed sections of the show.

MOTIVATION

1. I will compost fruit, vegetables and other suitable waste at home
2. I will encourage others to behave in ways that help the environment
3. I will choose petrol with ethanol in it or suggest it to the person filling up
4. I will try hard to recycle everything I can at work, school or home
5. Even if it takes more effort, I will still behave in ways that help the environment
6. I will use 'green' power, like solar panels or buying green electricity
7. I will talk to friends and family about actions that help the environment

Items were measured pre and post creating a pre-motivation and motivation-change score. Specific scientific topics (e.g. green power) mentioned formed sections of the show.

VALUE

1. The show helped me understand things in my everyday life
2. The show was relevant to my life
3. The show had ideas that I can use myself
4. The information in the show was important to me

ENJOYMENT

1. enjoyment
2. delighted
3. happy

Enjoyment, interest and surprise were measured using the Differential Emotions Scale, which asks how frequently people felt a particular way during the show using a single word. The emotions measured this way had a clean factor structure and in contrast to other studies, interest and enjoyment factored out distinctly. For the enjoyment scale, 'joy' was changed to 'enjoyment' to be more in line with language used by the audience.

INTEREST

1. concentrating
2. alert
3. attentive

It is interesting to note that the survey used (but not the DES) also included the word 'interesting' which when included in factor analyses resulted in co-loading and other problems with factor structure between interest and enjoyment items. It appears the

term 'interest', as perceived by the sample, is hard to differentiate from enjoyment. Based on the DES items, and these results, it appears – strangely – when measuring interest, using the word 'interest' is not ideal particularly if the study also looks at enjoyment.

SURPRISE

1. surprise
2. astonished
3. amazed

CURIOSITY

1. curious
2. inquisitive
3. wondering
4.

This was a novel three item, one word scale to measure curiosity along with the DES emotions. It formed a discrete factor. Items aimed to measure both the information-seeking ('inquisitive') and D-curiosity/information-gap ('wondering') aspects of curiosity.

Appendix B: survey instruments

The following pages contain all survey instruments used in the research. Note instruments are reproduced slightly smaller than original surveys (which filled a full A4 page) to fit the formatting within this thesis. Copies of the survey used in *Booming,* which was originally landscape orientation over four pages, have been further reduced in size and presented in portrait orientation over two pages.

Booming for Beginners – survey

The information from this survey will be used for research by the Australian National University to help make better science shows. We need your help! **Please complete one survey per person. Parents, please use your discretion as to whether younger children complete a survey and your assistance is appreciated.** Thank you plenty for your time.

Age (please circle)

Below 5 5-9 10-13 14-16 17-20 21-30 31-40 41-50 50+

Gender (please circle)

Male female

Please tell us what you think about the following statements now you've seen the show.

	PLEASE CIRCLE one response per question				
I saw that parts of the show **related to my life**	**strongly disagree**	**disagree**	**neutral**	**agree**	**strongly agree**
I liked it when **audience members volunteered**	strongly disagree	disagree	neutral	agree	strongly agree
Seeing the show made me **happy**	strongly disagree	disagree	neutral	agree	strongly agree
I was able to **understand** most of what was going on in the experiments	strongly disagree	disagree	neutral	agree	strongly agree
It was easy to pay **attention** to the show	strongly disagree	disagree	neutral	agree	strongly agree
I wish the show could have been **longer**	strongly disagree	disagree	neutral	agree	strongly agree
I was **surprised** by some of the experiments	strongly disagree	disagree	neutral	agree	strongly agree
The show made me **wonder** about some things I saw	strongly disagree	disagree	neutral	agree	strongly agree

I would **like to see more** shows like this	**strongly disagree**	**disagree**	**neutral**	**agree**	**strongly agree**
Knowing about science is **important** to me	strongly disagree	disagree	neutral	agree	strongly agree
I thought the show was **interesting**	strongly disagree	disagree	neutral	agree	strongly agree
The things I learnt were **important** to me	strongly disagree	disagree	neutral	agree	strongly agree
Seeing the experiments made me feel **involved** in the show	strongly disagree	disagree	neutral	agree	strongly agree
I thought the show was **fun**	strongly disagree	disagree	neutral	agree	strongly agree
The way the presenter **explained** things helped me **understand** what was happening	strongly disagree	disagree	neutral	agree	strongly agree
During the show I **focused** on what was going on	strongly disagree	disagree	neutral	agree	strongly agree
The show was a **good** thing to come to	strongly disagree	disagree	neutral	agree	strongly agree
The show had some **things I had never seen** before	strongly disagree	disagree	neutral	agree	strongly agree
I was **curious** about what would happen in the experiments	strongly disagree	disagree	neutral	agree	strongly agree
The show made me **want to discover** more about science	strongly disagree	disagree	neutral	agree	strongly agree
I am **interested in anything** to do with science	strongly disagree	disagree	neutral	agree	strongly agree
I was **amazed** by the show	strongly disagree	disagree	neutral	agree	strongly agree

The show helped me **understand things in the world**	**strongly disagree**	**disagree**	**neutral**	**agree**	**strongly agree**
I liked when the presenter **made me feel part** of the show	strongly disagree	disagree	neutral	agree	strongly agree
I **enjoyed** the show	strongly disagree	disagree	neutral	agree	strongly agree
Some of the show **did not make sense** to me	strongly disagree	disagree	neutral	agree	strongly agree
I **watched everything** that happened in the show	strongly disagree	disagree	neutral	agree	strongly agree
I was **excited** to be coming to the show today	strongly disagree	disagree	neutral	agree	strongly agree
Some of the experiments were quite **tricky**	strongly disagree	disagree	neutral	agree	strongly agree
I will **try to find out more** about some things in the show	strongly disagree	disagree	neutral	agree	strongly agree
I will **think about the show** after I leave today	strongly disagree	disagree	neutral	agree	strongly agree
I **like science**, so I liked the show	strongly disagree	disagree	neutral	agree	strongly agree
The show was **boring**	strongly disagree	disagree	neutral	agree	strongly agree

Please turn over

Interesting things

Please list the three most **interesting** things about the show, briefly **why you found them interesting,** and **how long** you they kept you interested.

What was interesting?	**Why was it interesting?** (in a few words)	**How long was it interesting?** **(please tick)**
		[] a short time [] a long time
		[] a short time [] a long time
		[] a short time [] a long time

Enjoyable things

Please list the three most **enjoyable** things about the show, briefly **why you found them enjoyable,** and **how long** you enjoyed them for.

What was enjoyable?	**Why was it enjoyable?** (in a few words)	**How long was it enjoyable?** **(please tick)**
		[] a short time [] a long time
		[] a short time [] a long time
		[] a short time [] a long time

Any other comments

Thank you very much for your time.

If you would like to be involved in future research please complete the attached slip. Your responses in this survey will remain anonymous.

Shell Questacon Science Circus – video conference show survey

We'd really like to know what YOU thought of the show. Please note you don't have to answer if you don't want to, but we appreciate your input. Please **don't** write your name. Thank you!

Age: _____

I am a: O **MALE**

O **FEMALE**

Overall, what score would give this show out of 10?

1	2	3	4	5	6	7	8	9	10
O	O	O	O	O	O	O	O	O	O

Please COLOUR IN the circle that describes what you think about the show

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
I could see how the show related to things in the outside world	O	O	O	O	O
There were lots of activities for us to do in the classroom	O	O	O	O	O
Some things I learnt were different to what I had thought before	O	O	O	O	O
The show was interesting	O	O	O	O	O
I still have questions about what we saw in the back of my mind	O	O	O	O	O
We were able to talk to the presenters easily	O	O	O	O	O
I enjoyed the show a lot	O	O	O	O	O
The show made me very curious	O	O	O	O	O
There was good interaction with the audience	O	O	O	O	O
I was surprised by some of the experiments	O	O	O	O	O
I really liked the presenters	O	O	O	O	O
I had fun for the entire show	O	O	O	O	O
There are things I am still wondering about now the show has finished	O	O	O	O	O
It felt like the presenters were actually in the room	O	O	O	O	O
The information was about the right level for me	O	O	O	O	O
The presenters were very enthusiastic	O	O	O	O	O
There were exciting pictures and videos on the screen, not just the presenters	O	O	O	O	O
Sometimes experiments turned out differently to what I thought	O	O	O	O	O

Please turn over >>

Eugowra / Fire / 281010

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
Seeing the presenters on the screen was just as good as them actually being here	O	O	O	O	O
I was able to understand everything in the show	O	O	O	O	O
The presenters made us feel part of the show	O	O	O	O	O
The show had hands-on activities for us to do	O	O	O	O	O
The show helped me understand things in everyday life	O	O	O	O	O
The show was funny	O	O	O	O	O

Compared to when the Science Circus came to your school, what was **BETTER** with the video show?

_____

Compared to when the Science Circus came to your school, what was **WORSE** with the video show?

_____

Thinking back to the different Science Circus shows you've seen, which show did you like the most?

O when people came to the school

O when we used the video conference

O I liked both shows equally

What would make the **video** show better? Please give us your suggestions. _____

_____

Please COLOUR IN the circle that describes how you feel now you've seen the show

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The show made me want to discover more about science	O	O	O	O	O
I will think more about things in the show	O	O	O	O	O
The show encouraged me to keep studying science at high school	O	O	O	O	O
I feel really inspired after seeing the show	O	O	O	O	O
I'm lots more excited about science now than before the show	O	O	O	O	O
I will try to find out more about things in the show	O	O	O	O	O
I like science more now that I've seen the show	O	O	O	O	O

Thank you for doing this survey!

Going Ballistics survey – Australian National University

We'd really like to know what YOU thought of the show. Please note you don't have to answer if you don't want to, but we appreciate your input. Please **don't** write your name. Thank you!

Age: _____

I am a: O **MALE**
O **FEMALE**

Overall, what score would give this show out of 10?

1 2 3 4 5 6 7 8 9 10
O O O O O O O O O O

Please COLOUR IN the circle that describes what you think about the show

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
The show was exactly what I was hoping to see	O	O	O	O	O
I could see how the show related to things in the outside world	O	O	O	O	O
I had fun for the entire show	O	O	O	O	O
There was good interaction with the audience	O	O	O	O	O
Most stuff in the show was new to me	O	O	O	O	O
I really liked the presenter	O	O	O	O	O
The show was interesting	O	O	O	O	O
The information was about the right level for me	O	O	O	O	O
Some results were really unexpected	O	O	O	O	O
I enjoyed the show	O	O	O	O	O
Some things in the show made me very curious	O	O	O	O	O
There was lots of variety in the show	O	O	O	O	O
There are things I am still wondering about now the show has finished	O	O	O	O	O
Jokes and humour made the show better	O	O	O	O	O
I was surprised by some of the experiments	O	O	O	O	O
I thought the show was a good thing to come to	O	O	O	O	O
The presenter was very enthusiastic	O	O	O	O	O
I was able to understand everything in the show	O	O	O	O	O
The presenter made us feel part of the show	O	O	O	O	O

Please turn over >>

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
I really liked when audience members volunteered	O	O	O	O	O
I was interested in the show from start to finish	O	O	O	O	O
I could see how ideas in the show linked together	O	O	O	O	O
The show helped me understand things in everyday life	O	O	O	O	O
Curiosity was something I felt during the show	O	O	O	O	O
I still have questions about what we saw in the back of my mind	O	O	O	O	O
Sometimes experiments turned out differently to what I thought	O	O	O	O	O
The show was funny	O	O	O	O	O

Which part of the show **SURPRISED** you most and **why**? _____

_____

Which part of the show did you **ENJOY** the most and **why**? _____

_____

Which part of the show made you feel most **INTERESTED** and **why**? _____

_____

Please COLOUR IN the circle that describes how you feel now you've seen the show

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The show made me want to discover more about science	O	O	O	O	O
I will think more about the show after I leave	O	O	O	O	O
I will try to find out more about things in the show	O	O	O	O	O
I feel really inspired after seeing the show	O	O	O	O	O
I'm a lot more excited about science now than before the show	O	O	O	O	O
I still think science is **not** really for me	O	O	O	O	O
Seeing the show gave me a more positive view of science	O	O	O	O	O

Thank you for doing this survey!

Burning Issues survey – Australian National University

We'd really like to know what YOU thought of the show. Please note you don't have to answer if you don't want to, but we appreciate your input. Please **don't** write your name. Thank you!

Age: _____

I am a: O **MALE** O **FEMALE**

Overall, what score would give this show out of 10?

1	2	3	4	5	6	7	8	9	10
O	O	O	O	O	O	O	O	O	O

Please COLOUR IN the circle that describes what you think about the show

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
The show was funny	O	O	O	O	O
I could see how the show related to things in the outside world	O	O	O	O	O
I had fun for the entire show	O	O	O	O	O
There was good interaction with the audience	O	O	O	O	O
The show was relevant to my life	O	O	O	O	O
I really liked the presenter	O	O	O	O	O
The show was interesting	O	O	O	O	O
The information was about the right level for me	O	O	O	O	O
Some results were really unexpected	O	O	O	O	O
I enjoyed the show	O	O	O	O	O
The show made me curious	O	O	O	O	O
The information in the show was important to me	O	O	O	O	O
There are things I am still wondering about now the show has finished	O	O	O	O	O
Most stuff in the show was new to me	O	O	O	O	O
I was surprised by the show	O	O	O	O	O
Parts of the show reminded me of things I've seen or done	O	O	O	O	O
The presenter was very enthusiastic	O	O	O	O	O
I already knew some stuff we learnt in the show	O	O	O	O	O
The presenter made us feel part of the show	O	O	O	O	O

Please turn over >>

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
Sometimes experiments turned out differently to what I thought	O	O	O	O	O
There was lots of variety in the show	O	O	O	O	O
There were things in the show I have a personal interest in	O	O	O	O	O
I could see how ideas in the show linked together	O	O	O	O	O
The show helped me understand things in everyday life	O	O	O	O	O
I still have questions about what we saw in the back of my mind	O	O	O	O	O
I was able to understand everything in the show	O	O	O	O	O
Jokes and humour made the show better	O	O	O	O	O
The show had ideas that I can use myself	O	O	O	O	O

Did the show **change how you think** about **chemistry**? If so, how?_____

_____

Which part of the show made you feel most **INTERESTED** and **why**? _____

_____

Which part of the show did you **ENJOY** the most and **why**?_____

_____

Please COLOUR IN the circle that describes how you feel now you've seen the show

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The show made me want to discover more about chemistry	O	O	O	O	O
I will think more about the show after I leave	O	O	O	O	O
I will try to find out more about things in the show	O	O	O	O	O
I feel really inspired after seeing the show	O	O	O	O	O
I'm a lot more excited about chemistry now than before the show	O	O	O	O	O
I still think chemistry is **not** really for me	O	O	O	O	O
Seeing the show gave me a more positive view of chemistry	O	O	O	O	O
I'm more interested in chemistry now than before	O	O	O	O	O

Thank you for doing this survey.

(*Burning Schools* – pre survey)

Burning Issues PRE SHOW survey– Australian National University

We'd like to know what YOU think about chemistry. Please note you don't have to answer if you don't want to, but we appreciate your input. Please **don't** write your name. Thank you!

Age: _____ **I am a:** O **MALE**

O **FEMALE**

Please COLOUR IN the circle that best describes what you think.

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
I'm really interested in chemistry	O	O	O	O	O
I'd be willing to learn more about chemistry in my spare time	O	O	O	O	O
I would like to study chemistry at university	O	O	O	O	O
I think chemistry is boring	O	O	O	O	O
I want to learn more about chemistry	O	O	O	O	O
I think scientists using chemistry have a great job	O	O	O	O	O
Chemistry can be a lot of fun	O	O	O	O	O
I would like to find out more about chemistry careers	O	O	O	O	O
I find chemistry really inspiring	O	O	O	O	O
I will work really hard at chemistry at school	O	O	O	O	O
I think chemistry would be an exciting career	O	O	O	O	O
I will choose chemistry when I get to make subject choices	O	O	O	O	O
Chemistry is not something I'd consider doing as job	O	O	O	O	O
I get good marks in chemistry/science at school	O	O	O	O	O
I am confident when it comes to learning chemistry/science	O	O	O	O	O

Colour in ONE circle that best describes your science studies at school

O I do general science that includes chemistry with other sciences

O I **don't** do science as a subject at all

O I do chemistry as a subject at school

O I've done chemistry as a subject in the past **but dropped it**

Teachers: please select the option that describes what you teach

Thankyou for completing this survey!

Burning Issues survey – Australian National University

We'd like to know what YOU thought of the show. Please note you don't have to answer if you don't want to, but your opinions are valuable to us. Please **don't** write your name. Thank you!

Age: _____

I am a: O **MALE** O **FEMALE**

Overall, what score would give this show out of 10?

1	2	3	4	5	6	7	8	9	10
O	O	O	O	O	O	O	O	O	O

Please COLOUR IN the circle that describes what you think about the show

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
The show was funny	O	O	O	O	O
I could see how the show related to things in the outside world	O	O	O	O	O
I had fun for the entire show	O	O	O	O	O
There was good interaction with the audience	O	O	O	O	O
The show was relevant to my life	O	O	O	O	O
I really liked the presenter	O	O	O	O	O
The show was interesting	O	O	O	O	O
The information was about the right level for me	O	O	O	O	O
The show had ideas that I can use myself	O	O	O	O	O
I enjoyed the show	O	O	O	O	O
The show made me curious	O	O	O	O	O
The information in the show was important to me	O	O	O	O	O
There are things I am still wondering about now the show has finished	O	O	O	O	O
I was able to understand everything in the show	O	O	O	O	O
I was surprised by some of the experiments	O	O	O	O	O
Parts of the show reminded me of things I've seen or done	O	O	O	O	O
The presenter was very enthusiastic	O	O	O	O	O
I already knew some stuff we learnt in the show	O	O	O	O	O
The presenter made us feel part of the show	O	O	O	O	O

Please turn over >>

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
There were things in the show I have a personal interest in	O	O	O	O	O
I could see how ideas in the show linked together	O	O	O	O	O
The show helped me understand things in everyday life	O	O	O	O	O
I still have questions about what we saw in the back of my mind	O	O	O	O	O

Which part of the show made you feel most **INTERESTED** and **why**? _____

_____

Which part of the show did you **ENJOY** the most and **why**? _____

_____

Did the show **change what you think** about **chemistry**? If so, **how**? _____

_____

Please COLOUR IN the circle that describes how you feel now you've seen the show

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I'm really interested in chemistry	O	O	O	O	O
I'd be willing to learn more about chemistry in my spare time	O	O	O	O	O
I would like to study chemistry at university	O	O	O	O	O
I think chemistry is boring	O	O	O	O	O
I want to learn more about chemistry	O	O	O	O	O
I think scientists using chemistry have a great job	O	O	O	O	O
Chemistry can be a lot of fun	O	O	O	O	O
I would like to find out more about chemistry careers	O	O	O	O	O
I find chemistry really inspiring	O	O	O	O	O
I will work really hard at chemistry at school	O	O	O	O	O
I think chemistry would be an exciting career	O	O	O	O	O
I will choose chemistry when I get to make subject choices	O	O	O	O	O
Chemistry is not something I'd consider doing as job	O	O	O	O	O

Survey - HIV AIDS

Please answer the questions honestly and truthfully. Please **do not** write your name. There are no right or wrong answers. We want to know exactly what you think. Please note you do not have to answer if you do not want to, but we are very grateful for your participation. Thank you.

About you – please answer

Age: _____ **I am a:** **MALE** **FEMALE** **(PLEASE CIRCLE)**

Please tick the circle that says how you feel about the statements below. Please be honest.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I want to learn more about HIV and AIDS	O	O	O	O	O
I plan **not** to have sex until I am older	O	O	O	O	O
I am worried about catching HIV	O	O	O	O	O
I will **be faithful** to one partner, **IF** I have sex	O	O	O	O	O
I will **always** use a **condom, IF** I have sex	O	O	O	O	O
I think I can stay completely safe from HIV AIDS	O	O	O	O	O
I will talk about HIV AIDS with my **friends**	O	O	O	O	O
ABC (Abstain, Be faithful, Condomise) is the way I choose to live my life	O	O	O	O	O
I am sure I know all the ways a person can get HIV	O	O	O	O	O
It is OK to have unprotected sex **sometimes**	O	O	O	O	O
At the moment abstinence is the best choice for me	O	O	O	O	O
I will have a HIV test if I do something unsafe	O	O	O	O	O
I will **try hard** to find new information on HIV AIDS	O	O	O	O	O
I will talk about HIV AIDS with my **family**	O	O	O	O	O
I am sure I can behave in ways that keep me safe from HIV	O	O	O	O	O
I will do ABC (Abstain, Be faithful, Condomise) even if other learners **do not** do ABC	O	O	O	O	O

Survey - HIV AIDS science show

Please answer the questions honestly and truthfully. Please **do not** write your name. There are no right or wrong answers. We want to know exactly what you think. Please note you do not have to answer if you do not want to, but we are very grateful for your participation. Thank you.

About you – please answer

Age: _____ **I am a:** **MALE** **FEMALE** **(PLEASE CIRCLE)**

Please tick the circle that describes how you feel about the statements below.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I want to learn more about HIV and AIDS	O	O	O	O	O
I plan **not** to have sex until I am older	O	O	O	O	O
I am worried about catching HIV	O	O	O	O	O
I will **be faithful** to one partner, **IF** I have sex	O	O	O	O	O
I learnt a lot about HIV AIDS from the show	O	O	O	O	O
I will **always** use a **condom, IF** I have sex	O	O	O	O	O
I think I can stay completely safe from HIV AIDS	O	O	O	O	O
I will talk about HIV AIDS with my **friends**	O	O	O	O	O
ABC (Abstain, Be faithful, Condomise) is the way I choose to live my life	O	O	O	O	O
I am sure I know all the ways a person can get HIV	O	O	O	O	O
It is OK to have unprotected sex **sometimes**	O	O	O	O	O
At the moment abstinence is the best choice for me	O	O	O	O	O
I will have a HIV test if I do something unsafe	O	O	O	O	O
I will **try hard** to find new information on HIV AIDS	O	O	O	O	O
I will talk about HIV AIDS with my **family**	O	O	O	O	O

Please turn over >>

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I am sure I can behave in ways that keep me safe from HIV	O	O	O	O	O
I will do ABC (Abstain, Be faithful, Condomise) even if other learners **do not** do ABC	O	O	O	O	O

Do you think you will **behave** differently because you have seen the show? **How**? Please explain

_____

_____

_____

Tick the circle that describes what you thought of the show – give your honest opinion

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I was **interested** in the show	O	O	O	O	O
I thought the show was **complicated**	O	O	O	O	O
I thought the show was **boring**	O	O	O	O	O
I **enjoyed** seeing the show	O	O	O	O	O
I could **understand** the information in the show	O	O	O	O	O
Overall, I **liked** the show	O	O	O	O	O

Please write down what you thought about the show

What did you **like** about the show and **why**? _____

_____

What did you **NOT like** about the show and **why**? _____

_____

What other HIV AIDS issues would you like more information about? _____

_____

Thank you for doing this survey!

Australian National University – Sustain-Ability show survey

We'd like to know what YOU thought of the show. Please note you don't have to answer if you don't want to, but we appreciate your input. Please **don't** write your name. Thank you!

Age: _____

I am a: O **MALE** O **FEMALE**

Overall, what score would give this show out of 10?

1	2	3	4	5	6	7	8	9	10
O	O	O	O	O	O	O	O	O	O

Please COLOUR IN the circle that describes what you think about the show

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
The show was funny	O	O	O	O	O
I could see how the show related to things in the outside world	O	O	O	O	O
I had fun for the entire show	O	O	O	O	O
There was good interaction with the audience	O	O	O	O	O
The show was relevant to my life	O	O	O	O	O
I really liked the presenter	O	O	O	O	O
The show was interesting	O	O	O	O	O
The information was about the right level for me	O	O	O	O	O
The show had ideas that I can use myself	O	O	O	O	O
I enjoyed the show	O	O	O	O	O
The show made me curious	O	O	O	O	O
I think the information in the show was important	O	O	O	O	O
There are things I am still wondering about now the show has finished	O	O	O	O	O
Jokes and humour made the show better	O	O	O	O	O
The show surprised me	O	O	O	O	O
Parts of the show reminded me of things I've seen or done	O	O	O	O	O
The presenter was very enthusiastic	O	O	O	O	O
I already knew some stuff we learnt in the show	O	O	O	O	O
The presenter made us feel part of the show	O	O	O	O	O

Please turn over >>

	Strongly Disagree ☹☹	Disagree ☹	Neutral	Agree ☺	Strongly Agree ☺☺
I really liked when audience members volunteered	O	O	O	O	O
There were things in the show I have a personal interest in	O	O	O	O	O
I could see how ideas in the show linked together	O	O	O	O	O
The show helped me understand things in everyday life	O	O	O	O	O
I still have questions about what we saw in the back of my mind	O	O	O	O	O

Did the show **change how you think** about climate change? If so, how?_____

_____

Do you think you will **behave** or **make decisions differently** now that you've seen the show? ____

_____

_____

Please COLOUR IN the circle that describes how you feel after seeing the show

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I will think more carefully about things I do that affect the environment	O	O	O	O	O
I'm more likely to choose ethanol petrol or suggest it to the person filling up	O	O	O	O	O
I will do more to encourage others to behave in ways that are good for the planet	O	O	O	O	O
It surprised me how much energy you save by recycling	O	O	O	O	O
I'll make some decisions differently when it comes to environmental things	O	O	O	O	O
I feel more confident I will behave in ways that help the planet	O	O	O	O	O
I will talk to all kinds of people about the things I learnt today	O	O	O	O	O
I didn't know the benefits of using ethanol in petrol	O	O	O	O	O
I will try harder to recycle everything I can	O	O	O	O	O
I'm already doing everything I can to help the environment	O	O	O	O	O

Do you have any **suggestions** to improve this show? Are there things you **did** or **didn't** like? ____

_____

_____

Thank you for doing this survey!

Australian National University

Sustainability show survey

Please complete this survey BEFORE THE SHOW – Thank you ☺

Please note you don't have to answer if you don't want to, but we appreciate your input. Please **don't** write your name. Thank you!

Age: _____ **I am:** O **MALE**

O **FEMALE**

Please COLOUR IN the circle that describes what you think

	Strongly Disagree ☹☹	Disagree ☹	Neutral / unsure	Agree ☺	Strongly Agree ☺☺
I compost fruit, vegetables and other suitable waste at home	O	O	O	O	O
Petrol with ethanol in it is better for the environment than regular petrol	O	O	O	O	O
Solar and wind power create energy without making climate change worse	O	O	O	O	O
Recycling saves a huge amount of energy	O	O	O	O	O
I understand why different actions are good or bad for climate change	O	O	O	O	O
I encourage others to behave in ways that help the environment	O	O	O	O	O
I choose petrol with ethanol in it or suggest it to the person filling up	O	O	O	O	O
I try hard to recycle everything I can at work, school or home	O	O	O	O	O
Even if it takes more effort, I still behave in ways that help the environment	O	O	O	O	O
I use 'green' power, like solar panels or buying green electricity	O	O	O	O	O
People's individual actions can make a difference when it comes to climate change	O	O	O	O	O
I talk to friends and family about actions that help the environment	O	O	O	O	O

What best describes your thoughts about climate change (please select one only)?

O I think climate change is happening, but it's just a **natural change** in Earth's temperatures

O I think climate change is happening, and I think **humans are largely causing it**

O I **don't** think climate change is happening

O I have **no idea** whether climate change is happening or not

Australian National University

Sustainability show survey

Please complete this survey AFTER THE SHOW – Thank you ☺

We'd really like to know what YOU thought of the show. Please note you don't have to answer if you don't want to, but we appreciate your input. Please **don't** write your name. Thank you!

Age: _____

I am a: O **MALE** O **FEMALE**

Overall, what score would give this show out of 10?

1	2	3	4	5	6	7	8	9	10
O	O	O	O	O	O	O	O	O	O

COLOUR IN the circle that describes **how often you felt** the following during the show:

	Rarely or never	Hardly ever	Sometimes	Often	Very often
enjoyment	O	O	O	O	O
surprise	O	O	O	O	O
concentrating	O	O	O	O	O
delighted	O	O	O	O	O
curious	O	O	O	O	O
astonished	O	O	O	O	O
interested	O	O	O	O	O
inquisitive	O	O	O	O	O
happy	O	O	O	O	O
amazed	O	O	O	O	O
alert	O	O	O	O	O
wondering	O	O	O	O	O
attentive	O	O	O	O	O

Did the show change how you think or feel about climate change (please give details)?

_____

_____

Do you think you will take any action(s), big or small, because of what you have seen in the show (please give details)? _____

_____

_____

Please turn over >>

Please COLOUR IN the circle that describes what you think now you have seen the show

	Strongly Disagree ☹☹	Disagree ☹	Neutral / unsure	Agree ☺	Strongly Agree ☺☺
I will compost fruit, vegetables and other suitable waste at home	O	O	O	O	O
The show helped me understand things in my everyday life	O	O	O	O	O
Petrol with ethanol in it is better for the environment than regular petrol	O	O	O	O	O
Solar and wind power create energy without making climate change worse	O	O	O	O	O
The show was relevant to my life	O	O	O	O	O
Recycling saves a huge amount of energy	O	O	O	O	O
I understand why different actions are good or bad for climate change	O	O	O	O	O
The show was funny	O	O	O	O	O
I will encourage others to behave in ways that help the environment	O	O	O	O	O
I will choose petrol with ethanol in it or suggest it to the person filling up	O	O	O	O	O
The show had ideas that I can use myself	O	O	O	O	O
I will try hard to recycle everything I can at work, school or home	O	O	O	O	O
The information in the show was important to me	O	O	O	O	O
The presenter made us feel part of the show	O	O	O	O	O
Even if it takes more effort, I will still behave in ways that help the environment	O	O	O	O	O
I will use 'green' power, like solar panels or buying green electricity	O	O	O	O	O
There was good interaction with the audience	O	O	O	O	O
People's individual actions can make a difference when it comes to climate change	O	O	O	O	O
The presenter was very enthusiastic	O	O	O	O	O
I will talk to friends and family about actions that help the environment	O	O	O	O	O

Thank you very much for doing this survey

Appendix C: ethical approval and information sheets

Participant information sheet used at all shows except *HIV*:

Survey background information
Audience response to science shows

Aims of the research

This research aims to find out more about the emotions and outcomes an audience member experiences from watching science shows. This information will be used to make better science shows in future – I hope you enjoy them.

About the survey

The survey should take about 5-10 minutes to complete. The questions are about your response to the science show and are similar to those used generally in evaluating science shows. There are no known risks related to completing the survey. Please ask if you need more information on any questions.

Completing the survey is voluntary.

Data collected and privacy

No personally identifying information is collected on the survey.

Data will be stored securely and treated as confidential. The final data may be used in my thesis, at professional conferences, and/or published in academic journals.

More information / contacts

For more information or for the results of this study, please feel free to contact me at:

Graham Walker
Centre for the Public Awareness of Science, The Australian National University
Building 38A, Canberra, ACT 0200
Email: g.walker@anu.edu.au
Web: http://cpas.anu.edu.au
Telephone: 02 6125 9224

If you have concerns about how the research was done please contact:

Secretary, Human Research Ethics Committee
Research Office, Chancelry 10B, The Australian National University, ACT 0200
Email: human.ethics.officer@anu.edu.au
Telephone: 02 6125 7945

Thank you for your time.

Participant information sheet used at *HIV*:

Survey background information
HIV/AIDS Science Show research

Aims of the research

This research aims to find out what you thought of the HIV/AIDS science show and what effects it had. This information will be used to improve the show in future.

About the survey

The survey should take about 5-10 minutes to complete. The questions are about your response to the science show and other issues around HIV/AIDS. Some questions ask how you feel personally about HIV issues or think you will behave in HIV risk situations. You don't have to answer all the questions if you don't feel comfortable doing so. Please ask if you need more information on any questions.

Completing the survey is voluntary. You don't have to answer every question if you don't want to.

The survey is anonymous so please answer completely honestly. Please don't write your name on the survey.

Data collected and privacy

No personal details will be recorded during this research. Your answers will only be identifiable through your school and class, so your answers can never be linked back to you. Please tell us exactly what you think.

The survey results will be coded electronically and stored securely. The electronic data will use a coding system to identify which school and class you came from, so your actual school and class will not be recorded in the data. The final data may be used in my thesis, at professional conferences, in the media, and/or published in academic journals. Individuals, classes and schools will not be identifiable through this presented data.

Results of the research

If you would like to know the outcomes of the research, please contact the science centre after June 2010.

More information / contacts

For more information, please feel free to contact me at:

Graham Walker
Centre for the Public Awareness of Science, The Australian National University
Building 38A, Canberra, ACT 0200
Email: g.walker@anu.edu.au
Web: http://cpas.anu.edu.au
Telephone: +61 2 6125 9224 / Cell phone in South Africa (TBC on arrival)

If you have concerns about how the research was done please contact:

Secretary, Human Research Ethics Committee
Research Office, Chancelry 10B, The Australian National University, ACT 0200
Email: human.ethics.officer@anu.edu.au
Telephone: +61 2 6125 7945

Thank you for your time.

THIS IS A SYSTEM-GENERATED E-MAIL. PLEASE DO NOT REPLY. SEE BELOW FOR E-MAIL CONTACT DETAILS.

Dear Mr Graham Walker,

Protocol: 2009/330
Interest, enjoyment and motivation in science shows

I am pleased to advise you that your Human Ethics protocol received approval by the Chair of the Science/Med DERC on 24 July 2009.

For your information:

1. Under the NHMRC/AVCC National Statement on Ethical Conduct in Human Research we are required to follow up research that we have approved. Once a year (or sooner for short projects) we shall request a brief report on any ethical issues which may have arisen during your research or whether it proceeded according to the plan outlined in the above protocol.

2. Please notify the committee of any changes to your protocol in the course of your research, and when you complete or cease working on the project.

3. Please notify the Committee immediately if any unforeseen events occur that might affect continued ethical acceptability of the research work.

4. The validity of the current approval is five years' maximum from the date shown approved. For longer projects you are required to seek renewed approval from the Committee.

All the best with your research,

Yolanda

Yolanda Shave
Ethics Manager
Office of Research Integrity
Research Office
Chancelry Building 10B
The Australian National University
Canberra, ACT 0200

E:human.ethics.officer@anu.edu.au or
yolanda.shave@anu.edu.au
W: http://www.anu.edu.au/ro/ORI/Human/human_index.php
T: (02) 6125 7945
F: (02) 6125 4807

*please note I am now working part-time hours until further notice
8:30 am - noon Monday-Friday

CRISCOS Provider Code: 00120C

THIS IS A SYSTEM-GENERATED E-MAIL. PLEASE DO NOT REPLY. SEE BELOW FOR E-MAIL CONTACT DETAILS.

Dear Mr Graham Walker,

Protocol: 2009/616
HIV science show

I am pleased to advise you that your Human Ethics protocol received approval by the Chair of the Science and Medical DERC on 21 January 2010.

PLEASE NOTE: Could the researchers consider including a local researcher in their team, if appropriate, in order to assist in the development of local research capacity?

For your information:

1. Under the NHMRC/AVCC National Statement on Ethical Conduct in Human Research we are required to follow up research that we have approved. Once a year (or sooner for short projects) we shall request a brief report on any ethical issues which may have arisen during your research or whether it proceeded according to the plan outlined in the above protocol.

2. Please notify the committee of any changes to your protocol in the course of your research, and when you complete or cease working on the project.

3. Please notify the Committee immediately if any unforeseen events occur that might affect continued ethical acceptability of the research work.

4. The validity of the current approval is five years' maximum from the date shown approved. For longer projects you are required to seek renewed approval from the Committee.

All the best with your research,

Kim

Ms Kim Tiffen
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http://anu.edu.au/ro/ORI/Human/human_index.php

CRISCOS Provider Code: 00120C