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Blood and Bones: The Influence of the Mass Media on Australian Primary School Children's Understandings of Genes and DNA

Jenny Donovan · Grady Venville

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Abstract Previous research showed that primary school children held several misconceptions about genetics of concern for their future lives. Included were beliefs that genes and DNA are separate substances, with genes causing family resemblance and DNA identifying suspects at crime scenes. Responses to this work 'blamed' the mass media for these misunderstandings. This study aimed to determine whether that blame had any foundation by examining the media habits and conceptions about genes and DNA of Australian children. With little prior research considering the influence of entertainment mass media on children's academically relevant knowledge, this was an exploratory study with a mixed modes design. Data were collected by detailed media questionnaires and face-to-face interviews with 62 children aged 10–12 years, and subjected to content and thematic analysis. Specific mass media examples children reported using were examined for genetics content. Results indicate 5 h/day of media use, mostly television including crime shows, and that children perceived television to be their main source of information about genetics. Most children (89 %) knew DNA, 60 % knew genes, and more was known about uses of DNA outside the body such as crime solving or resolving family relationships than about its biological nature and function. Half believed DNA is only in blood and body parts used for forensics. These concepts paralleled the themes emerging from the media examples. The results indicate that the mass media is a pervasive teacher of children, and that fundamental concepts could be introduced earlier in schools to establish scientific concepts before misconceptions arise.

1 Introduction

> Perhaps from the perspective of history, the most important scientific breakthrough of this century may be seen in time, to be neither nuclear fission, nor interplanetary flight, nor even informatics, but the fundamental building and basal molecular biology which permits the human species to look into

J. Donovan (✉) · G. Venville
University of Western Australia, Perth, WA, Australia
e-mail: jenny-donovan@hotmail.com

G. Venville
e-mail: grady.venville@uwa.edu.au

itself and find, at last, the basic building blocks of human and other life. Who knows where this discovery will lead the imaginative human mind? Lawyers, and indeed citizens everywhere, should begin thinking about the issue. In its resolution may lie the very future of our species. (Justice Michael Kirby 1994, p. 267)

Judges, scientists and science commentators (e.g. Brill 2008; Feetham and Thomson 2006) strongly argue that the twenty-first century will be the era of genetics, genomics, proteomics and molecular biology and that the explosive growth in understanding of these fields will revolutionise science, medicine, agriculture and the law. Brill (2008, last para) commented:

There is no doubt that genomics is the science of the 21st Century and little doubt that social change of the magnitude of the industrial revolution will follow, especially when genomics meets electronics and shakes hands with computer chips.

Citizens of the future will be called upon to make more decisions, from personal to political, regarding the impact of genetics on society. ‘Designer babies’; gene therapy; genetic modification; cloning, and the potential access to and use of personal genetic information are all complex and multifactorial issues. All raise ethical and scientific dilemmas.

To explore one example: the Australian legal system is based on jury verdicts. Jurors may be faced with complex information about DNA when called upon to decide a person’s guilt or innocence. What are the sources of potential jurors’ understandings about DNA? Older jurors may have received little or no formal instruction about DNA from their schooling. However, television shows that mention DNA include crime, forensics and medical shows. These are commonly shown in prime time and rate highly with the Australian population. In the USA, talk of a possible ‘*CSI* effect’ began when Willing’s (2004) *USA Today* report in August 2004 suggested that watching the TV show *CSI: Crime Scene Investigation* (hereafter referred to as *CSI*) influences jurors to acquit rather than convict unless there is enough scientific evidence to warrant the conviction.

To test this, the Maricopa County Attorney’s Office (MCAO) surveyed 102 experienced prosecutors who customarily talk with jurors after a case is closed. The MCAO report (2005) did not find significantly more acquittals linked to watching *CSI*, but found strong links between jurors watching *CSI* and expectations that substantial scientific evidence such as DNA tests should be presented in all cases. They found evidence of language transfer from *CSI*, with jurors in 40 % of cases using language not used at trial such as ‘mitochondrial DNA’, ‘latent prints’, ‘trace evidence’, or ‘ballistics’ (MCAO 2005, p. 6). Shelton, Kim and Barak (2006) surveyed 1,027 jurors, finding the same ‘tech effect’ of expecting more scientific evidence as the MCAO report; with Judge Shelton (2008) further commenting that people who sit on juries believe they learned more about science and technology from the media than from school.

In Queensland Australia, a controlled case study by Briody in 2004 examined 75 homicide cases in which DNA evidence was produced and 75 comparable cases in which no DNA evidence was produced. It found DNA evidence led to more convictions. The studies concur that for adults, watching *CSI* may lead to expectations of use of all possible scientific tests in court, though they do not clarify whether this extends to other similar TV shows such as *NCIS*.

Human genetics issues are not the only source of controversy. Referring to direct gene manipulation (as opposed to selective breeding), Cormick (2005) found that “public understanding of genetic modification, while growing, is still poor” (p. 16). He stated that only 31 % of Australians thought they could explain genetic engineering to a friend and only 19 % said they could explain the moving of plant genes into another plant (p. 16). This indicates that whatever education adult Australians have had about genetics, they have not been adequately prepared to comprehend what gene manipulation is and how it may be accomplished.

Consequently, if the twenty-first century is to be about genetics and its associated fields of genomics and proteomics, and if difficult decisions are to be made at individual, community and political levels, the world needs citizens who are sufficiently scientifically literate to be able to understand these issues well enough to inform their decision-making processes.

1.1 Scientific Literacy

Modern genetics, especially genomics, is a marriage between science and technology. It is not the only such field that is making new advances or encountering issues. Confronting climate change; creating earthquake early warning systems, coping with pandemics such as swine flu and many more all rely on considerable scientific and technological research. These issues also call for humans to assimilate complex information and make and act upon tough decisions. It is little wonder then that over the last 30 years, increasing attention in the educational literature has been paid to the notion of *scientific literacy*, also termed science literacy, public understanding of science, scientific culture and science for all (Roberts 2007). Two areas of general agreement are "that students can't be scientifically literate if they don't know any science subject matter" and that scientific literacy is for all students, not just those bound for careers in science (Roberts 2007, p. 735).

Broadly speaking, there are two visions of scientific literacy (Roberts 2007). Vision 1's more traditional stance looks at the products and processes of science itself, this is literacy *within* science. Vision 2's more innovative stance looks at situations with a scientific component that students are likely to encounter as citizens, it is literacy *about* science. Different countries have adopted different programs according to which vision they have selected. The USA has followed vision 1 with their *Project 2061: Science for All Americans* (American Association for the Advancement of Science [AAAS] 1989) whereas England has attempted to embrace vision 2 with their *Beyond 2000: Science Education for the Future* (Millar and Osborne 1998). What is happening in Australia?

A seminal report on science education in Australia was produced in 2001 by Goodrum, Hackling and Rennie, from which several recommendations emerged to guide the future of science education in this country. This report firstly created an ideal picture of science education, fundamental to which "is the belief that scientific literacy is a high priority for all citizens" (Goodrum et al. 2001, p. vii). Then the report presented an actual picture of current science education, described as "disappointing" (p. viii). The curriculum documents of the Australian states and territories provided a framework focused on developing scientific literacy, but "the actual curriculum implemented in most schools is different from the intended curriculum" (p. viii). For the purpose of their study, Goodrum et al. defined scientific literacy as:

> … the capacity for persons to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and wellbeing. (p. 15)

This definition permeates the Australian Science Curriculum statement (National Curriculum Board [NCB] 2009) that has emerged as a result of the report, and which is in the process of being implemented. It shares much with the USA's *Project 2061* and England's *Beyond 2000*, such as curiosity about science, being able to formulate questions and gather evidence in a scientific manner, having sufficient knowledge to enable them to apply their scientific understandings to their everyday lives and to be able to evaluate information. However, it omits a statement common to both the American and English documents, referring specifically to students being able to read scientific articles in the popular press with understanding and engage in conversations about the validity of the conclusions. Why do Australian documents lack this statement?

It appears the new curriculum has followed previous Australian state science outcome statements, which were solely concerned with science communication produced *by* students, usually at the end of an investigation, at the expense of considering how they decode the science communicated *to* them. Communication is a two-way process so understanding how students assimilate information received is just as critical as understanding how students express their own scientific ideas. Whilst media literacy has become widespread in most Australian curricula it is situated within the arts, and not yet applied to science.

Has the situation improved? Not yet. Goodrum et al. (2011) delivered a report on upper secondary school science that again compared the ideal for Australian science education with the actual; and again, the actual situation was disappointing. The percentage of 16–17 year olds studying a science has plummeted from 94 % in 1992 to 51 % in 2010; and the crowded curriculum is seen as preparation for university rather than as preparation for life. If Australia accepts this is the function of upper secondary school, the report points out this puts more pressure on compulsory schooling to develop science literacy.

1.2 Background to this Research

As researchers, we were faced with this scenario: currently, Australian adults are not scientifically literate with respect to DNA and genes, particularly gene technologies. The enacted science curriculum has not paralleled the intended curriculum, yet students of today will need sound understandings of genes and DNA in order to be scientifically literate citizens in the century of genomics. As Roberts (2007) attests, this requires all students to attain a measure of knowledge about genes and DNA sufficient to grasp the scientific basis of a variety of issues. With falling numbers of post-compulsory students choosing science (Goodrum et al. 2011), the exposure to genetics in the compulsory years may be their sole opportunity to develop science literacy in this field. There are indications that the mass media may be a possible source of at least some adults' information about DNA. However, the new curriculum is not designed to teach students media literacy in a scientific context, so it is likely they will find it challenging to decode any information gained from their encounters with the mass media. Clearly, research is needed into the possible influence of the mass media on students' understandings, and this was the overarching aim of the research reported here.

This research was grounded in our prior research (Venville et al. 2005, 2006), which indicated that many children in late primary school had already heard of DNA and genes, and those who had, were developing misconceptions about the physical relationship between DNA and genes. These included notions that genes and DNA are two totally separate entities, and that genes are responsible for familial relationships and similarities whereas DNA makes individuals unique and identifiable. We know that grasping the nature of the relationship between genes and DNA and their basic functions in living things is foundational, yet not easy even for teachers (Venville and Donovan 2005a). The concept of the gene itself is evolving (Meyer et al. 2011; Venville and Donovan 2005b).

The aims of this research were to ascertain the exposure of Australian children to the mass media, to explore the specific mass media with which the sampled children have come into contact for genetics information to see if this is a possible source of their knowledge; and to record the children's perceptions of the sources of their genetics information. Should this research uncover such informal sources of information and misconceptions about genes and DNA, it would raise two issues for discussion: (1) how could teachers of primary children respond? And (2) will misconceptions be dealt with by future compulsory instruction in genetics?

The first issue raises the thorny problem of whether primary children are capable of grasping biological information such as the physical relationship between genes and DNA. Prior research (Donovan and Venville 2005; Venville and Donovan 2007, 2008) indicated this is possible with appropriately concrete teaching methods (a model made of wool). In one part of this earlier research, Australian Year 2 children (7 years old), all from non-English-speaking backgrounds, were given just one lesson, using the model, about the physical relationship between DNA, genes, alleles, and chromosomes. During this lesson, they demonstrated their capacity to apply the model to humans by working out for themselves that identical twins would have the same DNA. The children received no further consolidation of these concepts from the researcher or the classroom teacher. When interviewed 2 weeks later, more than half of these 7 year olds could explain the physical relationship between DNA and genes, all could count the number of genes on the model, and some could identify an allele and a chromosome. These very young children also successfully translated this new knowledge from humans to cats and kittens. Similar findings (Venville and Donovan 2007, 2008) occurred with Year 5 children (aged 10 years), and this was considered a more suitable age for such basic instruction in genetics to begin, further supporting the decision to recruit children of these ages for this research.

The second issue, future instruction, draws attention to the new Australian curriculum (NCB 2009) that dictates that the only compulsory exposure to ideas about genes and DNA should occur in Year 10 (aged 15 years). The specific statement reads, "The transmission of heritable characteristics from one generation to the next involves genes and DNA" (p. 34). Without elaboration, teachers are not prompted to explain structural and functional relationships of genes and DNA, or to include alleles, polygenes, mutation, gene action through polypeptides or proteins, nor the influence of the environment on genes. This might be less problematic if most students selected Biology in the post-compulsory years of school, but only 24.7 % do (Goodrum et al. 2011). Thus the majority of Australian students may receive minimal exposure to specialized genetics concepts.

Consequently, the significance of this research into the possible influence of the media on the development of children's understandings is that it creates a clearer picture of the ways in which children begin to learn about genetics. Not only will genetics become academically relevant in high school and perhaps beyond, it may play an important role in the future lives of all children as they become adults. This research may also stimulate the visualisation of science communication by curriculum writers as a two-way process and encourage the application of the knowledge, understandings and skills of media literacy to the sciences as well as the arts. Further, this research may play a small part in the process that must occur to bring to fruition this concluding statement from Goodrum et al. in their 2001 report, "As we commence the third millennium, a greater priority must be given to building the scientific literacy of our people if Australia is to experience social and economic well-being" (p. xiv).

2 Conceptual Framework

This research fits Creswell's (2003) notion of qualitative research exploiting an under-studied area and searching for emergent theory. It is more appropriate, therefore, to speak of a conceptual framework rather than a theoretical one (Rocco and Plakhotnik 2009). Such a conceptual framework required consideration of two domains or contexts: what is known about media influence; and what is known about children's conceptions about genetics.

2.1 Media Influence

An extensive review of the media literature was undertaken to ascertain what was known about the influence of the media on people, and particularly, on children of the target age groups. Most research effort has gone into the media's influence on affective aspects such as opinions, beliefs and behaviours. This encompasses wide-ranging topics such as body image, eating disorders, violence, politics and elections, advertising, persuasion campaigns, and risk-taking, not directly relevant to this paper.

Research effort into cognitive influences of the mass media has focused on younger children learning to read (Rice 1983), with television shows such as *Sesame Street* being the target of considerable research. Much research was conducted in the 1980s when television ownership in North America was spreading rapidly, and some landmark studies such as Corteen and Williams (1986) yielded data from before and after the introduction of TV into Canadian towns, finding that TV slowed the acquisition of reading skills. Comstock and Scharrer (1999) noted that television socializes children to prefer non-demanding content, and Harrison and Williams (1986) found that 2 years of exposure to television decreased the creativity of children.

In 1988, Anderson and Collins specifically called for research into the influence of the media, particularly entertainment television, on what they termed "children's academically relevant knowledge" (p. 7, 40). Some 20 years later, we expected to find a considerable body of research relating the influence of the media to academic concepts, scientific or otherwise. However, this was not the case. Few studies could be found that even considered what academically relevant information is embedded in entertainment media, and the degree to which children are exposed to such content, let alone any possible influence on children exposed to such content. This meant that when this research began, little guidance was forthcoming about how to conduct such a study. Subsequently, some studies of the influence of medical TV shows on adult medical students (e.g. Weaver and Wilson 2011; Czarny et al. 2010) were found.

The closest comparable research was based in Western Australia by Low and Durkin (2001). This involved children from years 1, 3, 5, and 7 (ages 6, 8, 10, and 12), and considerations of police work on television and real life. Whilst reference was made to 'concepts' the research actually assessed perceptions and beliefs about police activities. The general finding was that what children saw on TV (i.e. an over-representation of using guns, breaking down doors, and high speed chases, and an under-representation of routine tasks such as paperwork) coloured their perceptions of what occurs in everyday life. However, only simple measures of the participants' exposure to crime shows, and their beliefs concerning the source of their information regarding police work, were taken.

Nelkin and Lindee examined the 'public image' of genes and DNA in popular culture, as in the 1990s they noted the influence of the mass media on their college students' notions of heredity and DNA (Nelkin and Lindee 2004). They found that both genes and

DNA are ubiquitous in popular culture and now have symbolic meanings beyond science (Nelkin and Lindee 2004, pp. 16, xii).

Despite this paucity of research, it must be widely assumed that students *do* learn from specific science shows, as many articles suggest using media to assist student learning. Examples include Pace and Jones (2009) use of web-based videos in the science classroom; Pryor (2008) using pop culture to teach introductory biology; Berumen's (2008) consideration of the ever-increasing appearance of biology in movies; and Thier's (2008) use of media in science to develop scepticism and critical thinking. These articles relate to students watching specific science shows in a classroom setting, whereas our interest is the influence of science concepts embedded in entertainment shows children watch at home.

2.2 Genetics

In their response to thousands of genetics essays entered into a competition for secondary students, Mills Shaw, Van Horne, Zhang and Boughman (2008) inferred a possible link between the mass media and genetics when they stated:

> The rapid advances in genetic research, the popularity of the topic in the news and in current popular television shows (e.g. *CSI: Crime Scene Investigation*), and the direct role that genetics plays in human health and reproduction make it a scientific discipline that everyone needs to understand. (p. 1157)

They identified a number of misconceptions from over half of the essays they had assessed, written by American students in 9–12th grades. This corroborated other work from the USA (such as Lestz 2008), as well as research from Europe (for example, Lewis and Kattman 2004) and from Asia (Chattopadhyay and Mahajan 2004). All of this research focused on secondary and tertiary students, and in all cases, the authors expressed frustration at the persistence of misconceptions despite genetics instruction. Collectively 24 different misconceptions were extracted from international genetics education research, ranging from beliefs that genes and DNA are separate substances, that humans have DNA only so it can be detected at crime scenes to solve crimes, deterministic beliefs about genes being for particular traits and diseases, to girls getting more DNA (or genes, chromosomes, genetic information) from their mothers and boys getting more from their fathers.

Some of these misconceptions are interconnected. As Lewis and Kattman (2004) pointed out, there is no intellectual impetus to consider a mechanism for gene action to produce a particular characteristic if there is a belief that the gene *is* the characteristic and the relationships between genetic entities are not understood. Others may arise from sloppy speech, some of which appears in the media. Mills Shaw et al. (2008) pointed out that scientists in the media should refer to the *mutation in the gene that leads to the disease cystic fibrosis*, instead of calling it the 'cystic fibrosis gene', and also:

> A cursory search of online news outlets yielded example headlines that could easily be misinterpreted, adding credibility to students' misconceptions. (p. 1165). For example, "Turning off suspect gene makes mice smarter". (*New York Times*, May 29, 2007)

Duncan, Rogat, and Yarden (2009) also mentioned several *New York Times* headlines, which, because of their compact form of language, could easily lead to misconceptions that there is, for example, a single gene that causes prostate cancer, such as "Scientists discover gene linked to higher rates of prostate cancer" (May 8, 2006).

Traditionally, genetics has been considered 'too difficult' for inclusion in curricula for students younger than 14–15 years. This is due to curriculum writers following Piagetian notions of those being the ages when a shift from concrete to abstract thinking often occurs. Certainly, at its highest levels, genetics is a tremendously complex subject challenging the highest of intellects. Science education researchers have identified the following difficulties:

- Genetics requires understandings at a molecular level, challenging for learners who do not yet have a firm grasp of atoms and molecules (Duncan et al. 2009).
- Processes and entities in genetic phenomena are invisible and experientially inaccessible to students (Marbach-Ad and Stavy 2000).
- Explaining genetic phenomena entails reasoning across levels of organisation from cell to whole organism (Duncan and Reiser 2007).
- Inappropriate treatment of concepts in high school textbooks (AAAS 2005) in which too much attention to detail occludes the 'big picture'.
- Students have difficulty understanding models as conceptual structures, and instead view them as physical replicas (like model airplanes are mini replicas of real airplanes), or just visual representations (National Research Council [NRC] 2005).

We do not deny these difficulties, but would point out that other intangible phenomena are taught at earlier ages. The Australian curriculum (NCB 2009) suggests dealing with forces in Year 4 (age 9), energy and electricity in Year 6 (age 11), and gravity in Year 7 (age 12). The same five points of difficulty apply to these topics, and an extensive literature of science misconceptions spanning 30 years from Osborne and Gilbert (1980) to Allen (2010) indicates it is far more challenging to devise accurate concrete models to teach these concepts than it is to use one to show that genes are made of DNA (Venville and Donovan 2007, 2008).

Also, other researchers, from Bruner (1960) to Lehrer and Schauble (2000) suggest that giving students opportunities to revisit science ideas and build deeper understanding over time, enables them to grasp and apply concepts that typically are not fully understood until several years later. Researchers such as Willingham (2006, 2008) and Hirsch (2006) contend that students need to be exposed to background knowledge from early ages in order for them to make sense of what they absorb from the world around them. In later years, Piaget (2001) himself wrote of children doing things and reflecting on what happened, until ultimately, they move from one cognitive stage to the next. However, current curricula rarely give children opportunity to engage with concepts beyond their current level of thinking or to revisit them periodically. As already mentioned, the new Australian curriculum (NCB 2009) indicates all genetics ideas should be introduced at one time only, in year 10 when students are 15 years old. There is no encouragement for teachers to foster gradual development of these concepts or to adopt any spiraling of the curriculum.

Willingham (2008, p. 39) further points out:

> For children and adults, understanding of any new concept is inevitably incomplete…. If you wait until you are certain that the children will understand every nuance of a lesson, you will likely wait too long to present it. If they understand every nuance, you're probably presenting content that they've already learned elsewhere.

It is possible then that educators are leaving it too late to introduce genetics concepts. As described in this introduction, children may have already learned some information about DNA from elsewhere, but, lacking enough background, may not have learned accurately. This research explores the possibility that for genetics, the mass media is that 'elsewhere' to which Willingham referred.

3 Methodology

3.1 Design and Participants

In the absence of similar prior research, an exploratory research design was employed (Trochim 2006). Exploration requires both analysis and synthesis of data, necessitating a flexible design collecting wide-ranging evidence rather than intensive evidence based on one situation. These considerations led to the adoption of a mixed methods mode (Creswell 2009), involving both quantitative and qualitative approaches in tandem so that the overall strength of the study was greater than either approach alone. Two tools, one primarily quantitative (a questionnaire administered to individual members in class groups of children) and one primarily qualitative (semi-structured individual interviews) were used. The design, methods and tools were approved by our university's ethics committee prior to commencement.

3.1.1 Research Questions

Table 1 shows the research questions and the research tools employed.

3.1.2 The Researchers

As this research was to comprise a doctoral study, and particularly as the sampling involved personal travel over large distances, all data collection was performed by the first author. The second author, with extensive background in science teaching and research, was the thesis supervisor. The first author's experience encompasses some 30 years as a science educator at schools and universities, sustained involvement and previous employment with a state curriculum body, and several years of prior experience as the second author's research associate. This prior research involved many interviews with

Table 1 Research questions and associated research tools

Research question	Data collection
1. What genetics content do primary school children encounter in their favourite media? What types of mass media do Australian primary school children aged 10-12 years use and in what proportions? What are their favourite media examples? What is the nature of the specific genetics content in their favourite media examples?	Media questionnaire Purposive sampling of mass media nominated by students
2. What trends are seen in primary school children's ideas about genetics?	Semi-structured interview
3. Is there any evidence that entertainment mass media influences children's academically relevant knowledge of genetics? From where do the children themselves perceive that they learned information about genetics? Do statements made about genes and DNA in media samples watched by the children, particularly in the TV shows of interest, resemble statements made about genes and DNA by the children themselves?	Cross-referencing all data

children aged 7–17 years in areas closely related to this research (Venville and Donovan 2005c, 2007, 2008). Data were stored securely by the first author at all times. The first author was primarily responsible for data analysis with the support of a research assistant, who was a second blind coder and checker of data entry accuracy.

3.1.3 Sample Selection and Recruitment

Previous work (Venville and Donovan 2005c; Donovan and Venville 2006), indicated that year 5 children (aged 10 years) were very keen to learn about genes and DNA, yet by age 14 (Year 9), students were disinterested and misconceptions were entrenched. Therefore, children in Years 5–7 (ages 10–12) were selected for this research. The subjects of this paper are the 62 children (33 girls and 29 boys) that completed both the questionnaire and interview. Names used in this paper are aliases.

A stratified sampling protocol as shown in Table 2 was employed. Remote locations were included to ensure variation in access to television channels and specific TV shows. However, selecting locales with different-sized populations from coast to inland and different types of schools also ensured the inclusion of diverse children from a range of socioeconomic situations, providing a broad-spectrum approach to the investigation. Children's responses to questions about their country of birth and language(s) spoken at home confirmed sample diversity, with 10 % born overseas and 13 % speaking other languages, including 8 % speaking indigenous languages or Aboriginal English.

Recruitment involved 'cold canvassing' primary schools regarding their willingness to be involved in this research. The approach was made through the Principal to clarify the nature of the research, and what would be required from the school. Of seven schools approached, five agreed to participate. Accepting Principals were keen to be involved, judging this to be a good opportunity for children to learn about the research process through direct experience. One of the two schools that regretfully declined had just heard that the school would be closing at the end of the year; and in the other, the Principal had just resigned.

Table 2 Location and numbers of participant children in the research ($N = 62$)

Sample	N	Locale	School(s)	ICSEA score[a]	Academic performance[b]
1	18	Large inland city of 70,000	Established boarding school	1,037	Close to or above Australian average for all parameters
2	25	Mid-sized coastal town of 15,000	New day school (2nd year open)	1,023	Close to Australian average for all parameters
3	11	Small remote inland town of 2,500	2 small schools; 1 new, 1 old	759	Both were below Australian average for most parameters
4	8	Small remote coastal town of 3,000	Established day school	641	Substantially below Australian average for most parameters

[a] ICSEA is the Index of Community Socio-Educational Advantage, an indicator of socio-economic status. Scores are as shown on the Australian My School website (www.myschool.edu.au) for individual schools for the year of data collection. The Australian average = 1,000, 1SD = 100

[b] Academic performance refers to the results of national testing for six parameters of literacy and numeracy. On My School (www.myschool.edu.au), annual results for each school are compared with Australian averages. Table 2 provides a summary of the results obtained by years 5 and 7 children in each sample school for the year of data collection

Once the Principal gave permission for the research to proceed, approved information and consent forms were sent to the school for all children enrolled in Years 5–7 to take home. Children who returned a consent form signed by their parents/guardians and by themselves were included as participants in this research. Children and their parents/guardians were aware that the children could withdraw from the research at any time; none did.

Teachers engaged in informal discussions as the research progressed. In this way, teachers in each participating school informally indicated that children involved in the research were from a range of academic levels, and, to their knowledge, had received no prior formal instruction in genetics.

3.2 Research Tools, Methods, and Data Analysis

This section describes the tools, methods and products of analysis used in this study to answer each research question.

3.2.1 What Genetics Content Do Primary School Children Encounter in Their Favourite Media?

Three sub-questions guiding data collection to answer research question 1 are shown in Table 1. Data for the first two sub-questions were collected using a questionnaire; the third was investigated by researching the specific media samples named by the children.

The first author administered the questionnaire to each class group, so she could answer any questions about how to fill it in. Despite its size (double-sided A3 to provide room for answers) and apparent complexity, only a few younger children asked questions, indicating the design was appropriate for the target ages. Children took about 30 min to complete the questionnaire and all handed it back. This technique avoided the common known disadvantages of questionnaires of a poor response rate and lack of understanding of questions (Walonick 1993).

The questionnaire asked the children in-depth information about their media habits, preferences, and favourites; and collected detailed demographic data. As no prior research has sought such detailed answers from children regarding their media interactions, this was a novel design customised to these research questions. In order to establish validity, the questionnaire design was informed by approaches adopted in prior media research, including asking participants to recall the media used in the past week (Wiman and Newman 1989), and keeping diaries (Gauntlett and Hill 1999). Four key considerations arose from the literature: the approach should be appropriate to the age of the participants, not burdensome to complete, with an appropriate time scale for the range of media to be assessed, and designed to minimise skewed results due to perceptions of social acceptability of answers (Van Evra 2004). Given the ages of the children in this study, it was decided to ask them what they 'usually do' with time scales up to a year to incorporate potentially rare media interactions such as going to the movies. Specific question design was guided by Martin (2006), and answer scales, allowing all options including 'never' were informed by Borgatti (1996) and Waddington (2000). Both researchers are experienced science educators who adopted a consensus approach regarding the final wording of each question. The "Appendix" to this paper provides a full description of the questions asked as the actual questionnaire would not reproduce satisfactorily at reduced size.

To facilitate analysis, data entry was weighted to reflect the frequency of exposure (365 for daily, 12 for monthly and so on), and the number of hours recorded for duration scores. Multiplication of frequency and duration scores enabled the calculation of annual scores for each child, from which averages could be calculated for each type of mass media. In this paper, these data were represented by the column graph in Fig. 1. Qualitative data was condensed to form Table 3, enabling comparisons to be made.

Limited pilot sampling of genetics content from the mass media prefaced the main data collection phase to guide which specific TV shows to include in the questionnaire and to set weightings for analysis of the *TV shows of interest* (specific crime and family relationship shows). However, purposive sampling (Trochim 2006) was used to answer sub-question 3, only following up the media children nominated as their favourites. Thus, although the researchers may have encountered other examples of genetics content, these were not included unless specifically named by one or more children. Only advertisements regularly appearing in magazines or during TV shows children mentioned are included.

Media samples were directly viewed where possible, although use was also made of online records of synopses, particularly of TV shows with hundreds or thousands of episodes. Newspapers local to the participating children were sampled twice, once in print when in each district collecting data, and again, all in the same month for comparison of coverage by sample area, achieved online. Articles containing genetics content (as defined by the inclusion of words such as DNA, genes, genetics, and genome) were examined by thematic analysis, also known as conceptual content analysis (Krippendorf 2004). Some themes such as crime-solving and disease were predictable from the pilot sampling, but other content themes including family relationships, genetics of non-human organisms, and non-scientific uses of genetic terminology, emerged as natural groupings from the analysis of the 102 samples. Frequencies of occurrence for each theme were calculated as a percentage.

Specific genetics aspects and suites of words co-occurring with each theme also emerged from the content analysis. Early in the analysis it became evident that articles about crime-solving mentioned DNA more often than genes. Counts were then made of the incidence of these words in each article, and as coding continued many other words such as alleles, mutations, and carrier were added to the list of words to be counted, ultimately generating suites of words common to each theme. Typology (Patton 2002) was used to explore the presence of these themes in other genetics-rich media, namely TV shows and magazines, though as sample boundaries were less defined by time, frequency data were not calculated.

Genetics content was rated for scientific accuracy as follows:

- None—no explanation offered
- Poor—gross errors of content
- Fair—reasonable attempt to explain at least some terms
- Good—adequate and accurate explanation
- Difficult—good explanation but at a very high level

As the first author was the only genetics expert with access to the data, two copies of the articles were made. The articles were blind-coded twice for scientific accuracy with an intervening interval of 6 months; the consistency rate of 94 % indicating that this rating system was able to be applied consistently. The six articles rated differently were positioned between fair and good; ultimately three were assigned to each group. The results of this media sampling aspect of the overall study are presented in Tables 4, 5 and 6.

3.2.2 What Trends are Seen in Primary School Children's Ideas About Genetics?

The data addressing this question were collected by face to face individual interviews. Most of the questions had been used and validated in our previous research, for which the first author of this paper was the main interviewer of children from 7 to 17 years (Venville and Donovan 2005c, 2007, 2008). The only new questions in this study involved asking the children about their perceptions of sources of their genetics information and what DNA might be used to find out. As before, a “less formal” (Cohen and Manion 1989, p. 307) semi-structured protocol (Creswell 2005) was chosen to yield rich qualitative data about the conceptions of the children. All interviews in this study were conducted by the first author. Thus, it was expected that repeating and paraphrasing questions in response to direct queries or body language would be necessary to achieve negotiated meaning.

The complete interview protocol with examples of probing questions is in the “Appendix”. In brief, pictures of cats and kittens were used to elicit initial understandings of inheritance, and whether children spontaneously named DNA or genes as the mechanism of inheritance, or whether they had only heard of these terms when asked. Questions transitioned from cats to humans, probing children’s understandings of biological functions of DNA and/or genes. The interview then transitioned from previously validated questions to the new questions specifically designed for this research.

At all stages, interviewees were allowed time to volunteer answers before being prompted by further questions. Field notes were used to record an outline of the interview, sequence of answers, facial expressions, hand gestures, and whether answers were prompted or spontaneous. These notes assisted the transcription of the audio tapes for analysis. They acted as a non-verbal cue to the respondent that their answers were important (McKay 2006), and provided a logical reason from the child’s viewpoint for the repetition and/or rephrasing of their answers back to them, which helped ensure that the correct meaning had been gleaned. Children also were reassured that there was no expectation that they would know all the answers, and that their ideas were also of interest. From the interview, counts were made of the numbers of children who correctly answered individual questions, to determine, for example, how many knew where DNA is located, that genes are made of DNA, or linked DNA to solving crime.

The children’s answers were assessed in light of their youth, as none gave technically correct answers to some of the questions. For example, no child said the nucleus for the location of DNA or genes, so the ‘correct’ answer was *in cells*, and ‘partly correct’ was *everywhere*. Similarly, for what DNA/genes do, the most correct answer offered was that *DNA is information*, and for how does it work, the most correct answer offered was *it produces messages that tell other organs how to grow and work.* No child mentioned the production of polypeptides or proteins. Misconceptions were identified from the 24 known misconceptions gathered from existing research. Novel misconceptions, that is, those not known from previous research, were identified. Both quantitative and qualitative results from this aspect of the study are summarised in the results section in Tables 7 and 8.

3.2.3 Is There Any Evidence that Entertainment Mass Media Influences Children’s Academically Relevant Knowledge of Genetics?

Two sub-questions for research question 3 are shown in Table 1. As mentioned previously, the data for the first sub-question regarding sources was collected in the interview, forming a break between the discussion of the biological functions of genes and DNA and ways in which humans might use DNA to find out things. This data is shown in Fig. 2. The second sub-question was answered by cross-referencing of all the quantitative and qualitative data, generating the column graphs based on questionnaire data forming Figs. 2 and 3. Constant comparative data analysis (Creswell 2005) of the genetics content themes that emerged from the media samples and from the interviews yielded Table 9.

3.3 Reliability

Initial coding and documentation of a coding scheme for the participant data were performed by the first author, a subject expert. The research assistant used the documented scheme to independently code 32 % of the samples. Intercoder reliability was 80 %; issues being legibility of the children's handwriting on the questionnaire and vague statements making it hard to decide which misconception they were expressing in the interview. The researcher and assistant revisited the source data, listened again to the tapes and discussed each inconsistency to reach consensus. This led to a few amendments to the coding scheme, and re-coding of all data sheets. The conceptual content analysis of the media samples for themes, and particularly to ascertain the suites of words, relied on counting words actually printed in the articles. Consequently intercoder reliability was highest for this data at 92 % on a subset of 49 % of the articles, errors due to simply missing words.

4 Results

4.1 What Genetics Content Do Primary School Children Encounter in Their Favourite Media?

4.1.1 Types of Mass Media Used by Australian Primary School Children

As described in the methods, children's media use was summarised by combining data describing the frequency and duration of use to calculate average annual scores. These scores show the average use, in hours per year, of each type of media. Figure 1 shows the average annual scores for the eight types of media used by these 62 children.

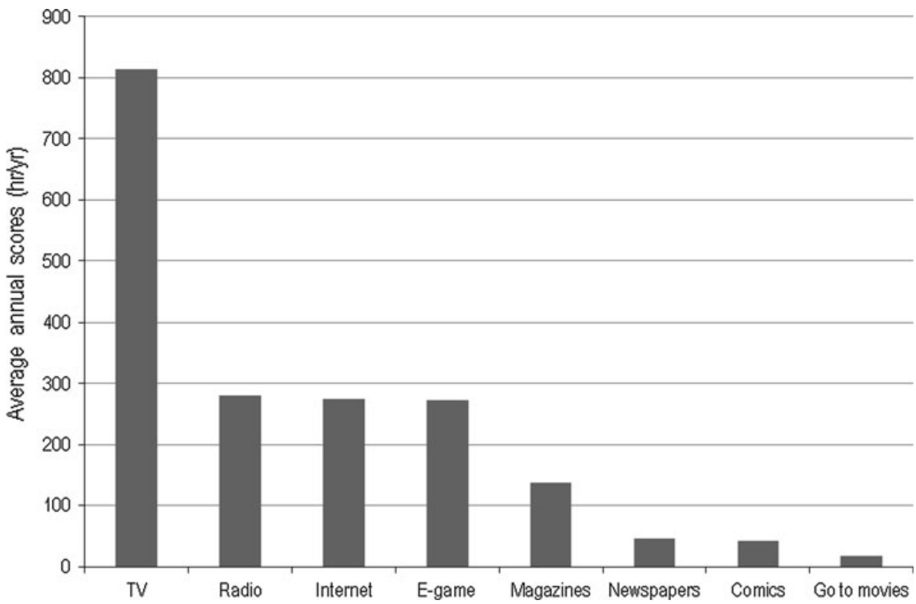

Fig. 1 Average annual score for children's use of each type of mass media ($N = 62$)

Figure 1 shows the dominance of television over all other media and the prominence of the electronic media over print media. E-games take precedence over magazines and comics. Movies were popular but viewed at home via live TV, video, DVDs and the Internet. Going to the movies was the least common media interaction for these children.

The data in Fig. 1 translate to an average of 5 h 10 min of media interaction per day, with a wide range from a minimum of 24 min to a maximum of 13 h 19 min. Evidence from children's rising times and bedtimes showed that to achieve the higher levels, some children were engaging with multiple media at one time. There was no evidence of the children being untruthful or giving politically correct answers. Some freely admitted to spending more than 5 h at a time with TV or an E-game, and despite it being their rarest media interaction, they correctly estimated how much time they would spend at the movies.

4.1.2 Favourite Media Examples

Each child could nominate up to three personal favourites for each type of media, a maximum of 186 mentions (votes) possible for each media type. Table 3 shows that TV polled the highest, with only three children not nominating any favourite TV shows, although some only nominated one or two shows. Table 3 also shows how many different examples of each type of media were mentioned, the top three favourites of each type of mass media, and how many times each specific favourite was mentioned. Note that radio and newspapers were different in each school's locality so are not included.

4.1.3 Nature of Genetics Content in Their Favourite Media Examples

Analysis showed that minimal genetics content was found in comics, E-games, and radio programs nominated by the children. One-third of the websites mentioned involved games, and it was impossible to know what specific content children accessed on YouTube and Google. Consequently those four media types will not be further considered in this paper.

Of the three most popular movies, *Avatar* was based around a theme of genetically engineered hybrids operated by genetically matched humans. However, with its novel 3D presentation in many theatres, the special effects, and other pervasive themes such as jungle story, star-crossed love story, imperialism, and deep ecology, it is

Table 3 Number of media nominated and top three favourites of the 62 participant children

Type of mass media	Favourite 1	Favourite 2	Favourite 3
60 TV shows, 153 votes	*The Simpsons* (19)	*Home and Away* (17)	*Disney* (7)
46 Websites, 121 votes	*YouTube* (16)	*Google* (12)	*Facebook* (11)
49 E-games, 110 votes	Nintendo DS (28)	Wii (23)	Playstation (21)
(2 types of answers)	Mixed games (43)	Sport (26)	Cartoon (13)
18 Comics, 32 votes	*Garfield* (7)	*The Simpsons* (5)	*Phantom* (3)
34 Magazines, 85 votes	*Girlfriend* (12)	*Dolly* (12)	*Total Girl* (11)
79 Movies, 139 votes	*Twilight* (10)	*Avatar* (8)	*Up* (7)

questionable as to how much genetics information children would have gained from this movie. Only four other movies out of the 79 that children nominated had any genetics concepts. *Elf*, *Pokemon Forever*, *I Am Legend*, and *G Force* all have themes of genetic enhancement rather than the nature of DNA, so will receive no further consideration in this paper.

This leaves three types of media: television, newspapers, and magazines. These were found to contain considerable genetics content, so were subject to further analysis and description. The genetics content of children's favourite TV shows such as *The Simpsons* was studied in detail, but will not be reported here. This paper focuses on the thematic aspects of the analysis.

Whilst newspapers are not used by the children for long periods of time, only 20 % of them said they never look at one, so it is possible that most children are gaining some genetics information from this medium. The genetics content themes were first identified in the newspaper samples though were subsequently identified in television and magazine content. The typology in Table 4 introduces these themes and indicates their presence in these three media types.

Other minor themes such as archaeology, genome sequencing, and recombinant DNA, occurred in low levels in only one type of media, so were not included in Table 4. Table 5 provides further explication of the top six themes, found in all three media types, with detailed description of one or more examples.

As described in the methods, as these themes emerged, it became evident that each regularly focused on one aspect of genetics content (such as DNA, gene, or genetics) and that a suite of associated words helped to define each theme, as detailed in Table 6.

From Table 6 it may be surmised that the journalists of Australia have tacitly agreed to restrict certain words for use with different themes. There is little overlap between the themes in terms of their associated words. It is possible to skim an article and identify the gist of the content merely by certain words catching the eye. If the eye sees 'DNA, blood, evidence' the article is about solving a crime, whereas if the words 'gene, mutation, carrier' are obvious, the article is about a genetic disease.

Articles in newspapers and magazines were often accompanied by a limited selection of stock photos, including the DNA helix, a gloved hand holding a vial and a micropipette, and a close-up of the lenses of a light microscope. Of these, the microscope is the least scientific since DNA and genes are not visible under such an instrument. Overall, in terms of accuracy of genetics content of print articles, 41 % offered no explanation, 19 % were judged poor, 24 % were judged fair, only 13 % were judged good, and a further 3 % were difficult.

Like Nelkin and Lindee (2004), the authors observed that DNA and genes, or visual symbols such as the double helix, appear to be ubiquitous in the media. The phrase *World Champ Gene*[1] was observed by the research assistant on the electric motor of a radio controlled model racing car. There appears to be no end to ways in which genetics content creeps into the modern world. It is clear that children are exposed to a variety of information about genes and DNA in most of the media with which they come into regular contact, though the specifics of what they encounter will vary with their individual media choices.

[1] *World Champ Gene* on a Speed Passion brushless radio controlled car motor (October, 2011).

Table 4 Genetics content themes emerging from newspapers, magazines, and television

Genetics themes	Newspaper articles ($N = 102$)	Magazines	Television
Genetic disease	28 % of articles e.g. Alzheimer's, fragile X	Articles in 'real life' magazines	Hospital shows e.g. *Grey's Anatomy*
Solving crime	27 % of articles e.g. DNA nabs rape duo in *Sunday Mail*[1]	*Woman's Day*[2]—low copy DNA & missing Maddie McCann	Crime shows e.g. *CSI, NCIS, Bones*, also *Home & Away*
Family relationships	2 % of articles e.g. disputed paternity of celebrity babies	*Woman's Day* & TV guides—celebrity paternity cases	*Find My Family, Can We Help? (Lost And Found), Neighbours*
Personal identity	2 % of articles e.g. adoption issues	*That's Life!*[3]—dentists to the dead	*The Simpsons, Big Bang Theory*, news
Non-human genetics	13 % of articles e.g. GM crops and foods	*Better Homes & Gardens*[4]—GM foods	*Futurama, Big Bang Theory*
Non-science content	7 % of articles e.g. Roald Dahl's DNA in Harry Potter[5]	*Girlfriend*[6]—DNA puts the muse in musician	*The Simpsons, King Gee/Gene* ad
'Good' genes	6 % of articles e.g. twins show niceness is in female genes[7]	*Women's Weekly*[8]—ageing and telomeres	
Diet, weight, fitness	6 % of articles e.g. GenoType diet[9]	*Better Homes And Gardens*[10]—beat genes and lose weight	
Identify sex/gender	Chromosome test to check athlete female[11]	*Girlfriend*[12]—why boys & girls different	

[1] Giles, D. *Queensland Sunday Mail,* "DNA nabs rape duo" (August 16, 2009)

[2] (No author), *Woman's Day,* "DNA tests prove Maddie's body was moved" (Jan 9, 2008)

[3] Middleton, A. *That's Life!* "We're dentists for the dead" (n.d., 2010)

[4] (No author), *Better Homes and Gardens,* "What's your eco-footprint?" (July, 2011)

[5] Griffin, M. *The Western Herald*, "Harry Potter confronts the test of time" (July 13, 2011)

[6] Dalzell, S. *Girlfriend,* "Putting the 'muse' in musician: 10 reasons why guy rockstars are oh-so-hot right now!" (November 29, 2007)

[7] Hood, M. *The Morning Bulletin*, "Niceness is in your genes: study" (February 11, 2011)

[8] Allardice, P. *The Australian Women's Weekly,* "Take years off your telomeres" (May 24, 2010)

[9] Hinde, S. *Queensland Sunday Mail,* "Diet's in your blood… and in your genes" (September 13, 2009)

[10] (No author), *Better Homes and Gardens,* "Belt tightening" (June, 2010)

[11] Malone, A. *Queensland Sunday Mail,* "I know my daughter: Gender row sickens father" (August 23, 2009)

[12] (No author), *Girlfriend,* "Why boys and girls are soo different" (June 4, 2007)

Table 5 Specific examples of the appearance of genetics themes in the media

Genetics theme	Specific example(s) in media mentioned by the children
Genetic disease	In a newspaper article about Fragile X, it or another disease/disorder was mentioned 36 times, gene 17 times, *premutation* 15 times, and *mutation* four times with no explanation of the difference, or of *carrier,* mentioned 18 times[1]. Such repetitive language and lack of explanation was typical of this theme
Solving crime	Crime shows e.g. *CSI, NCIS*, feature visuals of people collecting blood, saliva swabs, fingerprints, hair, skin samples, semen and other bodily fluids to test and identify suspects. Rarely explaining the science, samples go into machines that regularly churn out an answer just in time to satisfy an impatient team leader. Such visuals may explain why an 8 year old boy scratched his sister's would-be abductor to get the man's DNA under his fingernails, because he had seen on *NCIS* that would identify the man[2]
Family relationships	Australian TV show, *Can We Help?,* ran a *Lost & Found* segment bringing families together. One case, over two years, involved DNA tests to ensure two men really were brothers. These were explained particularly well[3]. Soaps like *Neighbours* and *Home and Away* occasionally feature DNA paternity tests
Personal identity	In *Lisa The Simpson*[4], Lisa (the smart one) is very concerned that she has inherited the *Simpson gene*, which makes her father Homer dumb. This 'gene', which contributes to baldness and laziness, is apparently expressed only by males, being on the Y chromosome, but it can't have the opposite effect on girls, as mentioned in the show, as girls lack the Y chromosome. Another example is Bart Simpson writing on the board 'Genetics is not an excuse'[5]
Non-human genetics	Following destruction of trial GM wheat crops by activists, an article by two celebrity chefs stated, "Even more troubling is the fact that GM plants have never been proven safe to eat. Through trial and error over many thousands of years, we have found what we can eat for health and nourishment and what we must stay away from" (Perry and Boetz 2011). The notion that trial and error is more effective than controlled scientific testing indicates these two chefs cannot be considered scientifically literate citizens
Non-science content	An actor claimed that playing a particular role had *changed his DNA*[6], other articles stated that the desire to maintain *integrity is in the DNA* of the Australian Football League[7], and that it is in the *aussie DNA* to enjoy horse racing[8]. In response to a controversial entry into a religious art competition, a churchman commented that a violent response to something offensive is *not in the genes of Christianity*[9]

[1] (No author), *The Morning Bulletin*, "Doctors unite to unravel autism gene" (July 26, 2011)

[2] (No author), *The Sydney Morning Herald,* "How little Nathan nailed his sister's would-be abductor" (May 19, 2010)

[3] *Can We Help? Lost and Found,* Episodes 7 and 8 (2009) and Episode 11 (2010). http://www.abc.net.au/tv/canwehelp/episodes/ Accessed 4 May 2012

[4] Goldreyer, N. (Writer), and Dietter, S. (Director). (1998). "Lisa the Simpson", Episode 195 [Television series episode]. In B. Oakley and J. Weinstein (Producers), *The Simpsons.* Fox Broadcasting Company

[5] Thacker, J. (Writer), and Sheetz, C. (Director). (2001). "I'm going to Praiseland", Episode 267 [Television series episode]. In B. Oakley and J. Weinstein (Producers), *The Simpsons.* Fox Broadcasting Company

[6] (No author), *The Morning Bulletin*, "Grenier says Entourage is in his blood" (July 24, 2011)

[7] Lane, S. *The Western Herald*, "Experts urge AFL inquiry on tanking" (August 4, 2011)

[8] Presnell, M. *The Western Herald*, "A man for all seasons set to take over the reins at NSW" (July 17, 2011)

[9] Taylor, A. *The Western Herald*, "Drag queen Christ sure to stir the passions" (August 7, 2011)

Table 6 Genetics focus of each theme and associated words

Genetics theme	Per cent of articles in this theme with this genetics focus	Associated words where >80 % of times this word appears is in this theme
Genetic disease	57 % on genes	Mutation, baby, carrier, chromosome
Solving crime	85 % on DNA	Evidence, forensics, cold case, database, blood
Family relationships	All on DNA	Paternity, siblings, parents
Personal identity	50 % on each of DNA, genetics	Genetic background, disease, personal rights
Non-human genetics	50 % on each of genes and DNA	Gene pool, evolution, GM, extinction, *mt*-DNA
Non-science content	78 % on DNA	No common words
'Good' genes	83 % on genes	Dominant, recessive, twins
Diet, weight, fitness	70 % on genes	Destiny, genetic make-up
Identify sex/gender	All on chromosome	Test, humiliation

4.2 What Trends are Seen in Primary School Children's Ideas About Genetics?

A summary of the knowledge responses is shown in Table 7, in percentages of total children ($N = 62$).

Table 7 shows that most children know that genes and/or DNA (some said both) are passed from parent to offspring indicating an understanding of inheritance. Others knew something passed between the generations but could not name the particles. Only one child, a Year 5 girl, had no concept of inheritance, or why offspring resemble their parents. When asked to spontaneously name the particle responsible for inheritance, 45 % said gene and 29 % said DNA. However, DNA was better known overall, with another 60 % of children having heard of it, totalling 89 %, whereas only another 15 % had heard of genes, totalling 60 %. Chromosomes are the relative unknowns, with no children volunteering that answer, and only 19 % of the children claiming to have heard of them. Only three children (5 %) had not heard of any of DNA, genes, or chromosomes and nearly all children knew or guessed that humans would have DNA or genes.

Considerably less was known about what DNA or genes are like and their functions. The location question raised many misconceptions, to be discussed in the next section. More children (26 %) knew that DNA/genes were very small or microscopic than could describe the shape (11 %), though a few said things like 'twisty ladder with dots' clearly describing the classic DNA model. Only 6 % correctly related DNA and genes structurally. Some guessed they were similar but 27 % thought they were completely different.

The children were far more able to suggest ways in which DNA may be used by humans outside of the body to find out things. Crime was the most popular use, mentioned by 77 %, and suggested first by half of these children, indicating it was foremost in their minds. Most children linked crime and forensics, although as the interview sheet in the "Appendix" shows, they were prompted separately, as forensics can be used for other purposes. Resolving family relationships was the next most popular use, mentioned by 64 %, with the children's answers separating into two subgroups, relating parents and children, including adoption cases, and relating other family members or identifying unknown soldiers. Using DNA to diagnose disease was less commonly mentioned (30 %) and only

Table 7 Knowledge responses of participant children ($N = 62$)

Genetics concept	'Good' understanding	'Partial' understanding
Inheritance	61 % associated genes and/or DNA with inheritance	36 % said inheritance is passing something from parents to offspring
DNA for inheritance	29 % spontaneously associated DNA with inheritance	60 % had only heard of DNA
Genes for inheritance	45 % spontaneously associated genes with inheritance	15 % had only heard of genes
Chromosomes	0 % had good understanding of chromosomes	19 % had heard of chromosomes
Humans have genes/DNA	97 % knew	3 % did not know
DNA location	11 % said in cells	16 % said everywhere
What DNA looks like	8 % could describe the size and shape of DNA	37 % could describe either size or shape of DNA
What DNA does	1.6 % information	16 % influences growth
How DNA works	1.6 % messages for organs	No other ideas
DNA & genes similar, why	6 % said genes made of DNA	55 % said similar
External uses of DNA	**Incidence**	**Total incidence**
DNA for solving crime	77 %—1st use for 38 %	Most linked these two together, saying both
DNA for forensics	40 %	
DNA for parent/child	47 %—1st use for 24 %	Few said both, so total incidence = 64 %
DNA—other family/soldiers	23 %	
DNA diagnoses disease	30 %—1st use for 5 %	
Other uses—cloning	12 %	Total for other = 36 %, 1st use for 26 %
General identification	8 %	
Research/experiments	8 %	

Table 8 Genetics misconceptions expressed by participant children ($N = 62$)

Misconception	Number and percentage of children with this misconception
DNA only in 'forensic' body parts i.e. blood, fingerprints, skin, hair, saliva	32 (51 %)
DNA confined to a few internal organs	11 (18 %)
Genes cause family resemblance, DNA makes person uniquely identifiable	13 (21 %)
Confusion of genes, traits, and gene expression	10 (16 %)
Unequal genetic information/expression from Mum and Dad	9 (14 %)
DNA is only for solving crime	8 (13 %)
DNA is only for resolving family relationships	8 (13 %)
Single genes exist for how we behave, act, think, personality	6 (10 %)
Can tell what a person looked like from a DNA sample	5 (8 %)
DNA is only for personal identity, to make you who you are	4 (6 %)
Inaccurate DNA/gene transfer from parent to offspring	7 (13 %)

5 % said this first. In all, 36 % of the children suggested other uses of DNA, of which cloning, general identification, and research or experiments were the main three. It was the first suggested use for 26 % of the children. Two children described maintaining and using DNA databases, another four mentioned machines to compare DNA.

It is clear from the results in Table 7, that whatever the source of these children's knowledge about genes and DNA, they are not gleaning much information regarding the biological functioning of these molecules. They are learning a lot about how it may be used outside the body.

The participating primary school children expressed a variety of misconceptions during the course of the interview, many of which were new in terms of what is known from previous research. Those misconceptions, both new and familiar, that were shared by several children are summarised in Table 8.

Table 8 shows that the prevailing misconception concerns the location of DNA and genes being restricted to some tissues and organs; it was expressed by about half of the children. All but two of these mentioned the blood; it was by far the most likely body part mentioned. Further, six of these children thought DNA really *was* blood, explaining it could be grouped, donated, and even that DNA changed colour according to how much oxygen it contained. Fingers/fingerprints were mentioned by 14 (22 %), skin by 11 (18 %), saliva and hair by six children (10 %) each.

The previously-known misconception linking genes to family resemblance and DNA to unique identity was mostly found in children who had a lot of knowledge, including those who achieved the top scores in the interview. This observation may imply it is a higher-level misconception and children need to have certain baseline knowledge in order to develop this idea.

The X chromosome is bigger than the Y chromosome, and boys receive an X chromosome from their mothers and a Y chromosome from their fathers, but some children extended this idea far beyond this inequality. Some believed girls get many more genes from their mothers and boys get more from their fathers. Others believed the inequality determines whom offspring will more closely resemble, or that resemblance to one parent means more of their genes are being expressed. Also, whilst it is likely that DNA and genes have some underlying contribution to how we behave, think, act, and to our personality, the simplistic idea that there are specific genes for each of these is inaccurate. In all areas, children expressed little understanding that the environment has any influence on gene expression; they held deterministic beliefs about genes and traits.

Novel misconceptions regarding the transfer of DNA and genes from parent to offspring were either extrapolation from how other things are transferred, such as food via the placenta or mother's milk; or more creative ideas, such as genes that go into the air, are injected into kittens, or are in skin cells that flake off and are inhaled by the mother. Two children ascribed negativity to DNA. Neil, a Year 6 boy said, "DNA looks like saliva, and if it's yellow, you're sick" and Parri, a Year 5 boy said "DNA is dangerous, it kills people". It is clear that the children in this study have heard of DNA and/or genes, and are forming both scientific and unscientific ideas about what they do and how they may be used.

4.3 Is There Any Evidence That Entertainment Mass Media Influences Children's Academically Relevant Knowledge of Genetics?

4.3.1 Children's Perceptions of Sources of Their Genetics Information

Children were asked during the interview about their perceptions of the sources of their genetics knowledge. Figure 2 shows their responses.

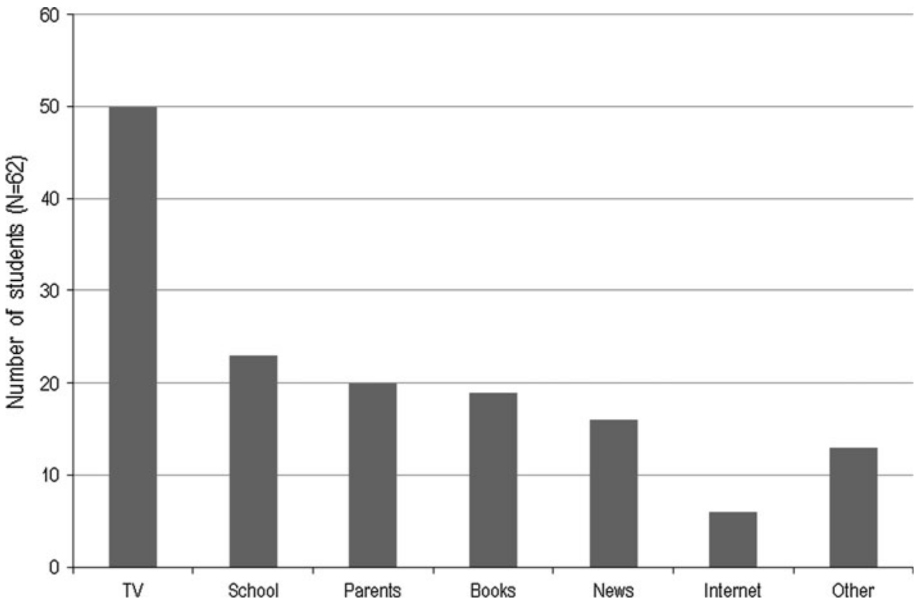

Fig. 2 Perceived sources of genetics information ($N = 62$)

Figure 2 shows that the children perceive television to be the most frequent source of information about genetics; it was named by 80 % of them, more than twice as often as any other source. Some children named only one source, others named as many as five. As explained in the methods, informal discussion with class teachers confirmed none of them had formally taught about genetics; though in two schools, teachers and some children recalled that genetics content arose by chance when discussing Jeans for Genes Day, a charity concept.

Some 15 (24 %) of the children had researched the topic of genetics themselves in the school library, books, and on the Internet. Others said they had overheard parental conversations about genetics rather than directly discussing it with them, whereas some families had talked about genetics after viewing a TV show. Some children said, "I don't really think I'd talk about that with my parents, we don't often talk about things like that". News refers to both television news bulletins and newspapers, and was a category created from the children's answers, as was the Internet. The 'other' category includes a grandmother, family friends such as a police officer, and medical personnel.

4.3.2 The Ten TV Shows of Interest

Figure 3 indicates viewing levels for each TV show of interest, based on weighted data for frequency.

Figure 3 does not show a clear-cut case of popularity, as not all the TV shows of interest were available free-to-air in all the sampling locations. Nineteen children lived in areas without access to the channel that screens *NCIS*, making its rate of viewing all the more remarkable. These 19 children also lacked free access to *Law and Order*. The TV shows *Bones, Find My Family, Can We Help?* and *Who Do You Think You Are?* were available to all children. Twenty-five children lived in an area where *CSI, The Mentalist, Cold Case,* and *Without A Trace* were

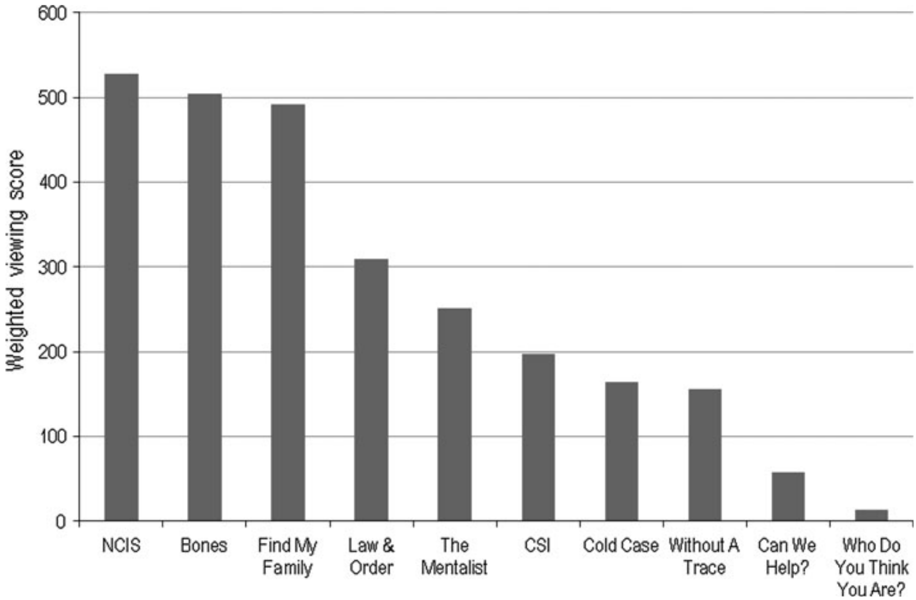

Fig. 3 Weighted frequency viewing data for the ten TV shows of interest ($N = 62$)

Table 9 Comparison of crime show incidents with children's words

Crime show incident	Genetics concept(s)	Children's statements
CSI[1]—blood spatter and DNA evidence showed one bullet killed identical twins	That identical twins have the same DNA	Prasai: You have DNA from a mix of your parents' DNA, which tells how you should look. Identical twins have the same DNA
CSI[2]—a fingerprint is lifted but doesn't match any in the database. DNA, apparently obtained from the fingerprint[a], shows 7 shared alleles between father and daughter. Visual is of a complicated readout from a machine	Fingerprints may contain DNA. DNA is shared between parents and offspring	Prasai: Well, you can take fingerprints, that's a DNA sample Annette: They use a special machine, and the machine will determine if it knows the DNA or if it's used that DNA before, and it will also show what the DNA looks like so you can compare it with other DNAs and find a culprit
NCIS[3]—buccal swabs and fingerprints taken and used to identify a thief. Light microscope is in view.	That DNA is found in the mouth/saliva. Fingerprints are used to identify people.	Neil: Can find who the criminal is from a fingerprint, blood or spit Adam: DNA is in the lines on your fingers

Table 9 continued

Crime show incident	Genetics concept(s)	Children's statements
NCIS[4]—matching DNA from a blood sample, showing an electrophoresis plate with blue dots, also a light microscope. The match shows an inherited genetic blood anomaly and discloses true paternity *Bones*[5]—very similar plot where DNA shows rare inherited disease and discloses true paternity and the killer. Light microscope is seen in the lab	DNA is in blood. DNA can be seen under microscope (misleading). DNA can also be seen on a gel plate. DNA is used to identify genetic diseases and disorders. DNA and these rare diseases are linked to paternity. Only one match is found when DNA tests are run (not necessarily true)	Diana: DNA is the blood type. It can be used to identify people through fingerprints, as no one's fingerprints are the same as each other. It can be used to diagnose disease, and also we can take blood from the person and the possible father and look for similarities. And for a robbery, the police would take fingerprints and put them in the computer, and that would tell them who it is. Or blood would work as well.

[1] Zuiker, A. E., Mendelsohn, C., Shankar, N., Tarantino, Q. (Writers), and Tarantino, Q. (Director). (2005). "Grave Danger Volume 1", *CSI,* Season 5, Episode 24 [Television series episode]

[2] Zuiker, A. E., Mendelsohn, C., Shankar, N., Tarantino, Q. (Writers), and Tarantino, Q. (Director). (2005). "Grave Danger Volume 2", *CSI,* Season 5, Episode 25 [Television series episode]

[3] Cardea, F., and Schenck, G. (Writers), and Smith, D. (Director). (2008). "Capitol Offense", *NCIS,* Episode 116 [Television series episode]

[4] Stern, J. (Writer), and Wharmby, T. (Director). (2008). "Heartland", *NCIS,* Episode 117 [Television series episode]

[5] Hanson, H., and Rosenthal, K. (Part 1), and Nathan, S., and Williams, S. (Part 2) (Writers), and Toynton, I. (Director). (2008). "Yanks in the U.K. Part 1" and "Yanks in the U.K. Part 2", *Bones,* Episodes 59 and 60 [Television series episode]

[a] Obtaining DNA from fingerprints has only been possible since 2003. DNA matches are made from only a few sites on the DNA, not the whole genome. Also, developing a latent print usually removes the chance of obtaining good DNA from it, none of which was explained in the show

not available free-to-air. Despite that, a few children in locations lacking free access to certain TV shows mentioned watching them, and when questioned, said their parents had bought DVDs or downloaded the individual shows from TV station websites.

Detailed studies were made of the scripts and visuals of the crime TV shows of interest, not reportable here. Instead, Table 9 compares summaries of incidents seen in some crime shows, genetics concept(s) underlying these incidents (not all of which are completely accurate), and statements from the children regarding those concepts.

Table 9 shows that there are marked similarities between the ways genetics concepts are presented in the analysed crime shows and the ways in which children speak about them. The repeated presence of the light microscope might explain the results in Table 7 that twice as many children knew DNA was microscopic, than knew its shape.

Further connections to family relationships are seen in other TV shows of interest such as *Find My Family* and *Can We Help?* For example, Willis, a Year 6 boy, stated "Oh, yes, on *Can We Help?* It goes right to the scene when they think they've found people, and they take DNA and see if they can match it". It is clear that themes in TV shows are the same themes that prevail in the genetics content in newspapers and magazines and in the descriptions of children's knowledge and misconceptions about genes and DNA.

Table 10 Comparing key findings about the mass media and the children's conceptions of genetics

Findings about mass media	Findings about children ($N = 62$)
Children spend substantial time with mass media, especially TV, which has considerable genetics content	Children perceive TV to be their main source of information about genetics, with 80 % of them mentioning it
Crime shows contain explicit genetics information aimed more at adults	Most children aged 10–12 watch crime shows, only 9 (14 %) said they did not view them
Genetics content falls into themes, especially genes and disease, DNA and crime, family relationships and identity	Children's conceptions fall into similar themes, children cited solving crimes, resolving family relationships, identification and diagnosing disease as uses of DNA
DNA is more often mentioned in the mass media except when related to disease and families	89 % of children had heard of DNA, 60 % had heard of genes, but more related genes to inheritance
Chromosomes are rarely mentioned in the mass media	No children spontaneously mentioned chromosomes, only 19 % had heard of them
DNA's location in the nucleus of cells is rarely if ever mentioned in the media	Few children know that DNA is located in all or most cells, no child mentioned nucleus
DNA is often portrayed as being in blood, fingerprints, saliva, skin, hair	51 % of children believe DNA is restricted to these parts of the body
The biological function of DNA, especially the production of proteins (or polypeptides) is rarely seen	Children know little about the biological function of DNA, none mentioned proteins or polypeptides
More is said and shown about the uses of DNA outside the body	Children knew much more about the external uses of DNA and 26 % believe it is only for solving crime or family relationships
Media explanation of the science of genetics is poor or absent	Children know relatively little about the science of genes and DNA
Crime show transcripts reveal similarities in plotlines, sources and uses of DNA, visual settings and dialogue	Children's word choices and understandings parallel what they have heard and seen on TV crime shows

5 Discussion

This study looked for evidence of influence by the mass media on the knowledge of genetics of 62 children in Years 5–7 (ages 10–12 years). Tables 4, 5, and 6 explicate the common genetics themes and language occurring in the mass media with which the children had come into contact. Tables 7 and 8 provide information about the children's understandings and misconceptions about genetics. Figures 1 and 3 show that participating children were in substantial contact with the mass media, particularly crime shows, and Fig. 2 shows that they attributed most of their genetics knowledge to television. Table 9 shows the substantial similarities between what is present in the mass media with which these children interact, and the conceptions they expressed and the language they used. Finally, Table 10 shows how the patterns of information provided in the media are similar to the patterns of genetics knowledge expressed by the children. Interested readers can access more of the children's own words in our recent paper (Donovan and Venville 2012). Collectively, these findings form evidence that we have uncovered a "phenomenon worthy of concern" (Anderson and Collins 1988, p. 7).

Anderson and Collins (1988) were concerned about "children's academically relevant knowledge" (pp. 7, 40) and, with our backgrounds in school teaching and research, so are we. We know the understandings children have and are continuing to gain from informal sources including the mass media will become relevant in their scholastic future. In year 10, 3–5 years from when this data were collected, most of the participating children will experience their one chance to learn the science of genes and DNA. In Australian schools, Year 10 genetics is taught by teachers whose background is not necessarily in biological science, let alone genetics. If the specific ideas children have constructed about the nature and uses of DNA are not taken into account in the classroom, children may be unable to fully comprehend the structural and functional relationships of genes and DNA, and the biological functions of these molecules (Venville and Treagust 1998).

Unless the children in this study select Biology in upper secondary school, they are unlikely to encounter more specialised instruction in genetics. Our own prior work with Australian Year 12 students (Venville and Donovan 2008) showed that they knew more scientific terminology than younger students; yet using the wool model uncovered persisting conceptual difficulties with the relationships between DNA, gene, allele and chromosome. These Year 12 students commented these conceptual relationships had never been specifically addressed by their teachers. However, in the schools participating in the research reported in this paper, the teachers commented they were used to researching many different areas for their teaching. They suggested that with a suitable model, they would be willing and able to tackle the basic structural relationship between genes and DNA, and to talk with children about what they see about genetics on television.

Undoubtedly, much more work remains to be done. For example, quasi-experimental studies could ascertain the impact of specifically challenging misconceptions such as those reported in this study in Year 10. Longitudinal studies also could assess the value of a spiral curriculum by commencing in Year 5 with two or three lessons acknowledging the children's pre-instructional conceptions and showing them the science behind key genetics concepts using a suitable model. These ideas could be revisited and expanded in say Years 7 and 9, prior to the main genetics instruction in Year 10. Further research could explore what and how adults learn about genetics from the mass media. Finally, more extensive studies are needed of the genetics content embedded in the mass media.

As educators, our concerns extend beyond academic performance. We want students to become scientifically literate citizens as they pass through the educational system we endorse and create. However, the National Assessment Program—Science Literacy [NAP-SL] (2010) report showed that the scientific literacy of Australian children in Year 6 (11 years of age) had *decreased* since 2006. Although not statistically significant, this is a disturbing trend. The report also showed that the scientific literacy of indigenous children and of those living in remote areas was significantly lower than that of children in metropolitan regions (NAP-SL 2010). We await the results of the next round of testing in 2012.

If the current approach to genetics education does not change, it is possible that by watching one forensic crime show each week for 1 year, children will have had more contact with the word DNA than they will encounter in their entire compulsory schooling. As Fig. 3 indicates, many children watch more than one such show a week, and are also bombarded with images and information about DNA in other TV shows, including soap operas and animations like *The Simpsons*, as well as in newspapers and magazines. *CSI* began in 2000, *NCIS* in 2003, *Bones* in 2005; the cumulative impact of years of exposure to genetics information in such mass media should be the focus of further research.

Can we blame the mass media? On balance, it seems the mass media teaches people a lot about how humans use DNA to solve crime, diagnose disease, and identify people. It may be that it is preparing people to be jurors in trials with DNA evidence; though they may then expect that evidence to be the norm in all cases, which in reality, it is not. The mass media does not appear to be producing a strong foundation in the basic science of genetics. This is hardly surprising; science is not the agenda of crime show writers. They seek to entertain, and to engage the interest of their viewers. Whilst the print media may include regrettable scientific inaccuracies in genetics as noted in this paper, the main effect of television shows is to generate interest in genetics. Educators should be grateful that depictions of DNA in crime and other TV shows encourage children, particularly girls, to pursue this branch of science (MacLeod 2005). It is up to educators to grasp the opportunities this interest provides and engage children with the science behind what they see. We personally know teachers who used the film *Jurassic Park* as a vehicle to discuss cloning. While that was undoubtedly good practice, it was a movie that children might see a few times. We assert that it is much more important to engage children in thinking about concepts embedded in TV shows they watch far more often, as well as confronting the scientifically inappropriate references to DNA in some newspaper and magazine articles. The responses of some children in this study indicate that informal classroom discussions are frequently recalled; thus lively discussions about what they have seen and heard about genetics in the mass media may ultimately help children to make informed decisions in their future lives.

Educators also understand the difficulty of challenging erroneous beliefs and misconceptions once they have become entrenched. There is a whole literature on the thorny issue of conceptual change, and how this might be achieved (for example, Posner et al. 1982; Driver and Oldham 1986; Venville and Treagust 1998). Logic tells us it would be preferable to avoid misconceptions wherever possible by introducing core concepts as and when children are ready for them, and allowing them time to incorporate and construct these concepts into a coherent framework. Can this be done?

Using educational research as their basis, Duncan et al. (2009) developed a spiral curriculum for the teaching and learning of genetics. This curriculum begins at Year 5, as we had suggested in our prior research, and the findings presented in this paper substantiate that choice. Duncan et al.'s curriculum is a useful guide as to which genetics concepts to introduce when. However, as this new research indicates that the term DNA is better known by some Year 5 children than genes, users of Duncan et al.'s curriculum might consider introducing both terms in Year 5, by explaining that DNA is the substance of which genes are made. Such spiralling of the curriculum would allow time for children to grasp fundamental concepts before overlaying them with the specific mechanisms and patterns of inheritance.

The issue of readiness for genetics merits consideration. Whilst 10 year olds are not ready for the intricacies of genetics, they do exhibit considerable interest in the subject, with one quarter of the children in this study having been moved to conduct their own research via the school library, books, and the Internet. Interest is by no means the sole deciding factor as to when to introduce specific content; however, it does indicate that the children judge themselves to be ready for at least some information about DNA and genes. Given that 97 % of these children knew that humans have DNA and genes, to learn that humans have genes *made of* DNA does not seem a great intellectual leap for them to take, especially with appropriate models. Learning that DNA is in nearly every cell would explain why scientists can extract it from many different samples to use for identifying people as they see on crime shows.

In the introduction to this paper, we made the point that in Australia, curriculum developers have neglected to include the requirement that students should be able to decode what they read and view in the mass media. In the USA, researchers such as Gadow et al. (1987) began working with second grade children on media literacy skills, and found that by sixth grade, they had acquired most of this information on their own. Australian children may not be fully media literate by Year 5 (age 10), but given their choice of interacting with media intended for adults, this appears to be an appropriate time to help them develop such skills. If children are not taught how to decode TV crime shows, for example, and realise that they are not an entirely accurate view of the process of solving crime, and be able to pinpoint the inaccuracies, then they cannot be said to be developing complete scientific literacy. The implications of children as young as 10 years of age being exposed to so much adult programming is itself an issue worthy of separate exploration. We stand by our notion that communication is a two-way process, and state further that children need to be able to decode what they receive before they can be reasonably expected to be able to encode it into forms suitable to transmit to other audiences in meaningful ways.

This study indicates that children from Year 5 (age 10) onwards are encountering the terms genes and DNA with no scientific background of the structural relationship between these two entities. Our earlier work developed a model that had good success with students' aged 7–17 in establishing sound understandings of the structural and functional relationships of genes and DNA (Donovan and Venville 2005; Venville and Donovan 2007, 2008). While this may seem premature in the light of further work yet to be done, we would urge curriculum developers and classroom teachers to at least consider introducing core concepts of genetics from an earlier age and implement a spiral curriculum. This is not envisaged as a major body of work that would displace significant portions of the existing curriculum. We achieved remarkable success with just one lesson with a Year 2 class (Donovan and Venville 2005; Venville and Donovan 2007); two or three lessons on each occasion would seem ample. These lessons could also help develop media literacy in science using the mass media as stimulus material.

6 Conclusions

This research is the first to explore the possible influence of entertainment mass media on children's academically relevant knowledge, particularly in genetics. We found that children aged 10-12 chose to have substantial interaction with the mass media (averaging 5 h 10 min/day), much of which has genetics content. Themes emerging from analysis of the genetics content of the mass media used by the participating children were similar to those emerging from analysis of children's conceptions of genes and DNA. Specifically, the most common themes related genes to disease, and DNA to solving crime, resolving family relationships, and personal identity.

The mass media was found to be poor in explaining the science of genetics, that is, the media rarely showed that DNA is present in the nucleus of most or all cells, nor portrayed the biological nature and function of genes and DNA. Likewise, few children could explain the science of genetics, none mentioned the nucleus or protein production, and only four could explain the structural relationship between genes and DNA. DNA was well known with 89 % of the children having heard of it, genes less so (60 %) and chromosomes poorly known (19 %). This approximates the ratio of coverage in the mass media, with chromosomes rarely mentioned. The mass media portrays DNA as being located in the blood and other tissue subjected to forensic examination, and presents its use for solving crimes and resolving family relationships such as paternity. Similarly, 51 % of the participating children believed DNA to be restricted to blood and other tissue collected for forensics, and offered several external uses for DNA.

The interest of the participating 10–12-year-old-children in knowing about genes and DNA is evidenced by 24 % of them having done their own research into the topic. If taught in developmentally appropriate ways, such as using a concrete model, we showed in prior research (Venville and Donovan 2007, 2008) that children may grasp the fundamental concepts of the nature and relationship of DNA, gene, allele and chromosome even at this early age. Such understanding is foundational for later incorporating more complex concepts about genetics and inheritance into their constructed frameworks.

This research sought to expose evidence for the influence of the mass media on the development of genetics knowledge in primary children. Whilst acknowledging that this research has not, and could not, demonstrate cause and effect, we believe it has answered the 'Is there any influence?' question raised by Anderson and Collins (1988, p. 7) and demonstrated that there is a 'phenomenon worthy of concern' (p. 7). The entertainment mass media cannot be 'blamed'; its job is not to instruct but to entertain. Further, it would seem likely that most primary children would know little genetics without the mass media, and TV shows raise interest in aspects of science. However, the mass media only portrays part of the story, and is no substitute for sound teaching at school. Giving children time to work with genetics on several occasions in their educational careers may result in improved educational outcomes and greater scientific literacy with regard to genetics for our future citizens.

We further contend that for students to ultimately become scientifically literate citizens, they must be taught how to decode the scientific information in the mass media with which they interact. They must be able to separate science from pseudoscience and non-science. They need both foundational knowledge upon which to construct a robust conceptual framework about genetics, and scientific media literacy skills. This will be important to their academic futures and to make informed decisions about genetics in their future lives.

To sum up, we close with recent words from Australia's Chief Scientist, Professor Ian Chubb, with which we wholeheartedly agree. We seek to do research that will help to inspire Australia… and perhaps others.

> Every day, we hear stories about climate change, cloning, genetically modified food, space exploration, DNA and new drugs to name a few. We need a community that can evaluate these claims and determine for themselves how they will respond and behave when given options. To make any choice at all especially one that is near rational, you need information and a base level of knowledge to help understand that information…In this climate, the value of science needs to be protected – from being manipulated by politics, misinterpreted in the media and from being dulled down in our schools. To do this, we need an inspired Australia. A national culture that appreciates the role science plays in every aspect of our lives, from our health to our economy. (Chubb, *Inspiring Australia's Scientific Culture* speech, CSIRO, March 13, 2012).

Acknowledgments Our thanks go to the participating children who gave informed consent to their involvement in this research and to the principals, teachers, and parents who also consented to allowing them to participate in this research. Our thanks also go to the three anonymous reviewers whose thorough comments yielded the refinement of this paper and of the doctoral thesis from which this paper is derived.

Appendix: Research Tools

Questionnaire

The administered questionnaire was double-sided A3 landscape in size; therefore it will not reproduce here. Its contents are described below, but if a copy of the original file is required, please email the corresponding author, jenny-donovan@hotmail.com.

The questionnaire was administered by the corresponding author to all children in class groups. The children took about 30 min to complete it.

Questions 1 and 2 had eight 'row' categories, A to H, being: Read comics? Watch TV, Use the Internet? Look in a newspaper? Listen to radio? Look at a magazine? Play an electronic game? Go to the movies? Both questions had the same instruction, which was to, "Tick (✔) the box that is your BEST answer for each part of this question". Question 1 asked, "How often do you" and the eight 'column' categories were: Every day, 2-3 times a week, once a week, every 2 weeks, once a month, once every 2–3 months, once a year, and never. This question was therefore assessing children's usual frequency of access to eight types of mass media. **Question 2** addressed duration of time, and asked, "What would be the USUAL amount of time you spend EACH time you". The 'column' categories were: Less than 1 h, between 1 and 2 h, between 2 and 3 h, between 3 and 4 h, between 4 and 5 h, and more than 5 h. Considerable thought went into the column categories, as it is known that the extent of the scale can influence answers in terms of indicating a possible 'normative value'. However, the children appeared to answer this question with relatively little regard for this, with some children ticking the 'more than 5 h' for activities such as watching TV and playing electronic games. The answers to the movies question also provided an indicator of the reliability of their sense of time as most children answered this question appropriately.

Question 3 also referred to the eight types of mass media, and asked, "What are your favourite or usual". The columns were double width, and headed Favourite 1, 2, 3, 4. The children were instructed to, "Write your answers in the boxes for this question, up to 4 favourites for each of A to H categories".

Question 4 focused on children's favourite characters in their favourite TV shows. This question proved to be the most problematic in terms of children working out how to answer it, so we discarded the data from this question. We would not use it again in future. These four questions were on the first side of the questionnaire. The children were instructed to turn it over and complete the other side.

Question 5 was a composite question focusing on the TV shows of interest. It asked, "Which of these TV shows have you watched and how often (when they're on air)? Which do you like or dislike? Do you have a favourite character?" Despite its complexity, the children generally answered it competently. Twelve TV shows were listed, though two were not watched by more than one child and thus were not considered in the analysis. The TV shows were the row categories and comprised: *CSI/CSI: Miami/CSI: New York* (any or all); *NCIS/NCIS: Los Angeles* (either or both); *Bones*; *Without a Trace*; *Cold Case*; *Find My Family*; *Who Do You Think You Are?*; *Can We Help?*; *The Mentalist*; *Law and Order* (any of the varieties of this show). *Insight* and *Weird Science* were the two that were dropped. There were 7 column categories, the first 5 of which were for describing viewing frequency. These were headed by the instruction to, "Tick (✔) the box that is your BEST answer for each part of this question" and the frequencies offered were: Yes, every week; Yes, most weeks; Yes, a few times; Yes, but only once or twice; and No, never watched this. The sixth column was headed 'Like or Dislike' with instruction to "Write L for like and D for dislike if you've seen the show". The final column was double width, with the instruction to, "Write the name of a favourite character if you have one". The Like/Dislike column was interesting with some children claiming to dislike shows they watch every week, and others claiming to dislike shows they have never watched. When queried (usually prior to the interview commencing), some children said, "Mum likes it so it's on every week" (often with a rueful expression), and others cited advertisements for the show as being the basis of their dislike and choice to not watch it. Some children wrote more than one favourite character when they simply couldn't choose between them.

Question 6 asked, "In your house, which TV channels are most watched by your family?" and the instruction was to, "Number the channels 1, 2, 3 etc. with 1 as the MOST watched. Don't number a channel you don't have or watch". This research was completed during the time when Australia was rolling out digital TV, and some locations had more access to new digital channels than anticipated. Thus the eight channels listed in the columns did not cover all eventualities, although this question did indicate those with access to paid TV and consequently a wider variety of shows. As a cross-check, generally the stations numbered in the top 3 were those upon which the children's favourite shows were aired, so it afforded some sense of the honesty of their responses.

Finally, the questionnaire ended with a section headed: NOW PLEASE FILL IN THIS INFORMATION ABOUT YOU, AND THEN YOU'RE DONE! THANK YOU!

This section collected demographic information, namely their first name and surname initial; date of birth; gender; country of birth; language(s) spoken at home; rising and bedtimes; and whether they lived in town or on an outlying property.

Interview

INTERVIEW PROTOCOL

Parts 1 and 2 comprise tested questions from previous research. Part 3 comprises new questions devised specifically for this research.

Part 1

Aim: To determine if interviewee understands how and why offspring resemble their parents and to see if the interviewee differentiates between visible characteristics (phenotype) and microscopic, abstract causal mechanisms such as genes, DNA or chromosomes (genotype).

Interviewer shows interviewee several pictures of adult cats and kittens. Note: pictures of dogs were used in our earliest research, but this was changed to cats to avoid sensitivities of Islamic children.

Question 1: What do you notice about these pictures? Let the children talk about them, guide them away from explanations that they are all doing different things to talking about the appearance of the animals. See if children spontaneously mention they are different ages, adults and kittens, but probe for that if necessary.

Question 2: Do you think any of the adult cats are parents of any of the kittens? If yes, go to Q. 3, if not; ask "Why not?"

Question 3: Which of the adult cats and kittens belong together as parents and babies? Often paraphrased as "Pick out an adult cat and a kitten where the adult could be the mummy or daddy of the kitten". Allow children to point out as many pairs as they like. When they point out some pairs, note them down, and ask "Why do you think so?" If they only give one feature, probe for more by asking "Can you give any other reasons why you think that?" Typical answers include they look alike, same coloured fur, but some children may notice finer features such as curly or straight coat, patterns of coloured fur, eye colour and so on.

If children are able to talk about genes, DNA, chromosomes, or a causal entity that is different from the physical characteristics, go on to part 2.

If they have not mentioned these things, ask them if they have heard of genes (differentiate from 'jeans'), DNA, and chromosomes, and ask them what they know about these entities. Then go on to part 2.

If they have no idea of inheritance, or not heard of these things at all, then reassure them it is OK not to know about these yet, and terminate the interview here.

The previous research in which these questions were used is reported in Donovan and Venville (2005) and Venville and Donovan (2005c; 2007; 2008). In this previous research (and again in this study), children had no difficulty in transitioning from cats and kittens

(Part 1) to humans (Part 2), given the way the transition was made, using whichever term they had spontaneously mentioned or said they had heard of in Part 1. Part 2 then focuses on their knowledge about genes/DNA, in terms of its nature, location and function in the body.

Part 2

Aim: To determine interviewee's understandings about the nature, location, and biological functions of whichever entity they linked with inheritance (DNA, gene or chromosome).

Question 5: You mentioned DNA/genes/chromosomes. Do you think that humans have DNA/genes/chromosomes too? If yes, go to Q. 6. If no, ask "Why not?"

Question 6: Where do you think DNA/genes/chromosomes are located in the body? If children stop at one location, ask them "Do you think they are anywhere else?"

Question 7: What do you think DNA/genes/chromosomes look like? Write down their description, take note of any gestures that are used to help them explain (e.g. hand movements indicating the spiral nature of DNA), or offer them paper and pencil to draw what they mean.

Question 8: What do you think DNA/genes/chromosomes do in the body? Often paraphrased as "What is their job?" Even though the question refers to 'in the body' some children may mention solving crime, identifying people, and so on. Note these answers under Q. 12 and re-focus the child on what it might do biologically.

Question 9: How do you think DNA/genes/chromosomes work? Often paraphrased as "How do they do (refer to what they said in Q. 8)?" or "Do you know HOW it might make this kitten (refer to one of their examples) the same colour (or whatever feature they had noted) as its parent?" or use a human example if they have mentioned their similarity to their parents. It was not expected that children of these ages would have detailed knowledge of protein synthesis, so it was their ideas, if they had any, which were of interest. Possible expected answers from previous research included ideas about recipes, instructions, or metaphors involving computers.

Question 10: What do you think is the same or different about DNA and genes? Probe whether children understand that genes are made of DNA. Ask why they think they are similar or different.

Part 3

Aim: To determine the source(s) of interviewee's knowledge about DNA/genes, and their ideas on what DNA can be used to find out beyond its biological functions.

Question 11: Where did you learn what you know about DNA/genes/chromosomes? Encourage them to mention more than one source if they can. Only once they stop offering ideas, probe for sources they have not mentioned, for example "Have you talked to your parents about genes and DNA?" "Do you remember seeing anything about DNA on TV?" If they mention TV, ask them to be more specific about which TV shows they recall it being mentioned.

Question 12: You mentioned (refer to a source, or a comment they have made about DNA). Besides what it does inside the body, sometimes DNA can be used outside the body to help people find out things. Do you know what it can be used for? Only once they stop offering ideas, probe for their possible knowledge about solving crime, forensics, resolving family relationships, disease and so on.

Thank interviewee, reassure them about their answers, and terminate the interview.

Part 3 of the interview was designed to lead from their biological knowledge of genes and DNA to their sources of that information. Interviews were conducted a few days after their participation in the questionnaire so that children would not be conditioned into mentioning only media sources. However, most children did mention TV, and this provided an ideal segue to the last question as shown. This aimed to probe for the desired knowledge without creating a misunderstanding that DNA has no natural function. Interviews were often closed with comments that they already knew quite a lot about genes and DNA, and that they would learn more about what DNA does in the body in high school.

The interview record sheet (actual size A3 to allow room for writing)

STUDENT FIRST NAME & INITIAL:____________________

SCHOOL:____

YEAR:______________ DOB: ______________

INTERVIEW DATE: _____________________

QN	What they can do	Yes/No	Comments	Score
1	Observes some are adults and others kittens without help			
2	Recognises some adult cats and kittens are related			
3	Which cat/kittens selected?			
	Why do they think they're related?			
4	What makes kittens look similar to adult cats?			
	Mentions genes, chromosomes or DNA spontaneously			
	Has heard of them when mentioned by interviewer			
	Spontaneous knowledge of genes/DNA/chromosomes			
	SUBTOTAL PART 1			
5	Knows humans have genes/DNA/chromosomes			
6	Where they think genes/DNA/chromosomes are located			
7	What they think genes/DNA/chromosomes look like			
8	What they think genes/DNA/chromosomes do			
9	How they think genes/DNA/chromosomes work in body			
10	What they think is similar/different about genes & DNA			
	SUBTOTAL PART 2			
11	Where did they hear about genes/DNA/chromosomes?	Parents		
		School		
		Reading		
		TV		
		Other		
12	What else are genes/DNA/chromosomes used for?	Crime		
		Forensics		
		Paternity		
		Diagnosis		
		Other		
	SUBTOTAL PART 3			
	TOTAL INTERVIEW SCORE			

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