The Influence of the Mass Media on Australian Primary Students' Understandings of Genes and DNA

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THE UNIVERSITY OF WESTERN AUSTRALIA

Declaration

This thesis contains published work, and/or work prepared for publication, **some of which has been co-authored.** The bibliographical details of the work and where it appears in the thesis are outlined below. The student must attach to this declaration a statement for each publication that clarifies the contribution of the student to the work. This may be in the form of a description of the precise contributions of the student to the published work and/or a statement of percent contribution by the student. This statement must be signed by all authors. **If signatures from all the authors cannot be obtained, the statement detailing the student's contribution to the published work must be signed by the coordinating supervisor.**

The following two papers have been published from this thesis. Both draw from a number of chapters, but neither appears in their entirety anywhere in this thesis. The first paper considered a subset of the media data, the second paper considered a subset of the participant data. Both papers were co-authored by the student and supervisor, with the following percentage contributions:

Conceptualization: Student 80%, Supervisor 20%

Data collection and analysis: Student 100%

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Student Signature ....

Coordinating Supervisor Signature ....

This thesis has been formatted according to the guidelines of the American Psychological Association (APA) (5th Edition), but with Australian English spelling. Tables have been formatted on an individual basis to enhance readability.

Acknowledgements

In reflecting on this doctoral journey, I want to acknowledge the many and varied influences that have led me here. Although my parents are deceased, I acknowledge the parts they played: from my father comes my scientific curiosity, capacity to ask endless questions, the desire to seek answers, the skills of scientific debate, the ability to see more than one side of an issue, and my love of reading and critical evaluation of knowledge. From my mother I gained my meticulous organisational skills, tenacity to persist, and, dare I say, my perfectionist streak that is reflected in this thesis.

My scholastic career featured inspirational primary school teachers in England and high school teachers in Australia. I am fortunate to have been a foundation student at what became and still is a highly respected school, Rossmoyne Senior High, staffed by excellent teachers. In particular, thanks to my English teacher, Mr Sainsbury, for the advice to study biological sciences at University rather than languages. He said it would improve my career options, in the knowledge that "the ability to write well will always be useful." How right he was!

My career as a teacher involved learning on the job at Mercedes College under the guidance of wonderful mentors such as Biology teacher Penny Hussey and English teacher Gem Ballantyne. My transition to tertiary teaching occurred under the influence of members of the Australasian Society for Human Biology (ASHB), in particular, the mentorship of Professors Charles Oxnard, Neville Bruce, and Len Freedman from UWA. Other significant mentors in this transition time were Professors Denis Goodrum, Mark Hackling, and Adrienne Kinnear from ECU, and Dr Sue Fyfe from Curtin. My first published journal article was written with Dr Lutz Slomianka and I thank him for teaching me the protocols of academic writing, especially the caution not to make the findings sound too exciting to be believable.

Thanks to networking with Dr Vaille Dawson, my career as a researcher began with Professor John Wallace at Curtin, from whose trust in me I learned so much. He was the first to suggest I should do a PhD, and while my life circumstances at the time were not conducive, I never forgot his absolute faith that I could do it. He suggested I work with Grady Venville, creating a collegial union that has changed the course of my life. It was with Grady that I learned and experienced data collection, analysis, and the writing and publishing of papers in educational research. Despite my having moved to Queensland, when I decided the time was right to do a PhD, there was no other choice

in my mind as supervisor. Had Curtin offered a place before UWA, we would have happily included our mutual mentor, Professor David Treagust, but UWA offered first, so Grady was solely charged with steering my doctoral journey. It has been a wonderful experience, full of joy, intellectual challenge and delight, and far less frustration and difficulty than I anticipated. This has been due to Grady's patience, rapid response, and excellent constructive feedback. In addition, her willingness and trust to know when to leave me alone to work things out and when to intervene, and faith that we could work almost entirely by email as I travelled around Australia during this time was essential to my success. She inspired me to produce an elegant thesis, and I trust this has been achieved. She deserves no less.

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Publications Arising from this Thesis

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Papers

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Donovan, J., & Venville, G. (2012). Exploring the influence of the mass media on primary students' conceptual understanding of genetics. *Education 3-13, 40*(1), 75-95.

Keynotes

Venville, G., & Donovan, J. (2012, May). *The impact of the mass media on children's conceptual understandings of genes and DNA.* Keynote presentation at the 3rd International Workshop of the Graduate Program PofaS: Educational Reconstruction at its Best: Fostering Teacher Education. Carl von Ossietzky Universität, Oldenburg, Germany, 7-10th May 2012.

Conference presentations

Donovan, J., & Venville, G. (2012, June). *Primary students' perceptions of the sources of their information about genes and DNA.* A poster and paper presented at the annual international conference of the Australasian Science Education Research Association (ASERA), Sippy Downs, Australia.

Donovan, J., & Venville, G. (2011, July). *Blood, bones, and crime: The mass media and students' conceptions of genes and DNA.* A paper presented at the annual international conference of the Australasian Science Education Research Association (ASERA), Adelaide, Australia.

Donovan, J. (2010, July). *The impact of the mass media on students' understandings of genes and DNA: Preliminary findings.* A paper presented at the annual international conference of the Australasian Science Education Research Association (ASERA), Port Stephens, Australia.

Abstract

Previous research with which I was involved concerned the genetics conceptions of Australian metropolitan students aged 10-15 years. Contrary to expectations based on the timing of the formal teaching of genetics in Australia in Year 10 (to 15 year olds), it was found that students as young as 10 years old were forming ideas about genetics, but that not all their ideas were scientifically correct. Chief among their misconceptions were ideas that genes and DNA were completely different entities, both structurally and functionally. Genes were thought to make people resemble their family members, whereas DNA was thought to make people individually identifiable, particularly as a prime suspect. When this research was presented, scientists, educators and public alike "blamed" the mass media for these misunderstandings. This doctoral research explored the foundation of that blame by examining the media habits and conceptions about genes and DNA of four regional samples of Australian primary students.

An exploratory, mixed modes design utilized data from detailed media questionnaires ($N = 141$) and face-to-face interviews with a subsample of 62 primary students aged 10-12 years. Based on the literature, these research tools were developed for this study, although the interview protocol also drew in part from that used in our previous research. The generated data were subjected to quantitative and qualitative analysis. Specific mass media examples used by participants were examined for genetics content.

Results indicate an average of five hours/day of media use, comprising mostly television. This viewing included DNA-focused crime shows rated for ages 15+ for 71% of the interviewed participants, and in all, 77% of them associated DNA with solving crime. The participants perceived television, particularly crime shows, to be their main source of information about genetics. Most participants (89%) knew DNA, 60% knew genes, and all interviewed participants knew more about uses of DNA outside the body such as crime solving or resolving family relationships than they did about its biological nature and function. Half believed DNA is only in blood and body parts used for forensics. Of particular interest was the finding that 27% of the participants had done their own research into genes and DNA. The participants' conceptions paralleled the themes emerging from the media examples. The results indicate that the mass media is a pervasive teacher of 10-12 year old students, and that fundamental concepts could be introduced earlier in schools to establish scientific concepts before misconceptions arise.

Chapter 1 - Introduction and Genesis of this Research

I was only 19 when, armed with a Bachelor of Science degree in botany and biochemistry but with no formal teacher training, I walked into a private school and taught my first Year 11 and 12 biology and human biology classes. It was scary to say the least, as my sole teaching experience was giving private guitar tuition, but it was also exhilarating and I became hooked. Mostly by accident, I had found my dream job. My father had to put aside his dreams of having a Nobel-prize-winning genetics researcher daughter and desist from paraphrasing George Bernard Shaw by saying, "Those who can, do, those who can't, teach." By the time he died nearly 20 years later, he was saying "those who can, do, but those who can do better, teach." The school had also taken a chance, but as the regular teacher had quit a week before school started, the principal decided I was a worthwhile risk. It was a happy accident for all concerned and, from a term's trial, I was to stay for 14 years and rise to the position of head of the science department.

One of my favourite topics to teach was genetics, and through reading and attending conferences, I kept up-to-date with this burgeoning field. Through my attendance at conferences, I became involved with the Australasian Society for Human Biology (ASHB) shortly after its inception, and thus came to know academics in my field from all the Western Australian universities. They encouraged me to step away from school to begin my university teaching career, teaching anything from stars to cells, and mosses to muscles, but often including genetics. I became well known in the local education community over the next 10 years, leading to a three-year position with the Western Australian Curriculum Council as the Curriculum Officer in charge of science during the implementation of the new *Curriculum Framework* (Curriculum Council, 1998). During this time, my love of genetics took a back seat, but my interest in science communication grew. This position involved copious writing and I learned firsthand that what seems clear to one person, may be ascribed a very different meaning by a second reader. I could see how misconceptions could arise simply from the way in which something was written or presented.

From there, I moved into academic research as an assistant and then an associate. Research became a new and equally satisfying career, culminating in my decision to enrol as a doctoral candidate. Consequently, the genesis of this study resulted from drawing the many threads of my background together. These threads include genetics,

student learning of genetics, and appropriate time to teach genetics, as well as misconceptions in genetics, and how misconceptions arise. Another aspect of my background, my interest in science communication, provoked me to consider the possible impact of the media on students' understandings.

As a research associate, I was involved with research addressing a gap in the literature about how children develop their understandings of genes, DNA and living things, by specifically targeting primary school children (Venville, Gribble, & Donovan, 2005). We found that children developed nonscientific ideas about genes and DNA long before school curricula formally address these topics. Presentation of this research to scientific and educational peers or to the public provoked a response of "blaming" the media for the children's ideas (Donovan & Venville, 2004). Part of our previous research involved interviewing expert geneticists to ascertain their vision of what students should know about genetics (Venville & Donovan, 2005b). Upon hearing the children's ideas, the experts were adamant in claiming that these misunderstandings arose from the mistreatment of genetics topics by the mass media. In this doctoral research, I wanted to find out whether that blame had any basis in fact, and if so, to present a cogent argument for the earlier introduction of these topics into the curriculum.

Aim of the Research

The overarching aim of this research was to explore possible links between the ways the concepts of genetics, especially genes and DNA, appear in the mass media and the development of primary students' misconceptions about the nature and function of genes and DNA. As I conceptualised the research process, I realised this would involve checking if the misconceptions we had previously uncovered were common to a wider sample of students, and to find out where the students themselves thought their ideas had come from. I would need to look at how the mass media presents information about genes and DNA and look for patterns in the messages presented. To draw it all together, I would need to know the extent of the students' exposure to the mass media, and explore links between this and their understandings.

Why genetics?

"The human genome underlies the fundamental unity of all members of the human family, as well as the recognition of their inherent dignity and diversity. In a symbolic sense, it is the heritage of humanity" (United Nations Educational Scientific and Cultural Organization [UNESCO], 1997). Just 10 years later, James D. Watson, the last survivor of the three Nobel prize winners who elucidated the double helix of DNA in the 1950s, took a look at his own sequenced genome and said, "I think we will have a healthier and more compassionate world 50 years from now due to the great technological advances we are celebrating here today" (soRelle, 2007, para.1). He is but one of many scientists and science commentators (e.g. Brill, 2008; Feetham & Thomson, 2006; Jegalian, 2000; *The Economist*, 2001) who argue that the 21st Century will be the era of genetics, genomics, proteomics and molecular biology. They explain that the explosive growth in understanding of these fields will revolutionise science, medicine, agriculture, and the law. For example, 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.

Feetham and Thomson (2006) stated, ". . . the knowledge about genomics is said to be to this century what the knowledge of infectious disease was to the last" (p. 4). Such ideas are not unique to the 21st Century. Some authorities were aware of the potential impact of the Human Genome Project even as it was unfolding in the late 20th Century. As early as 1994 in Australia, Justice Michael Kirby stated

> 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 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. (p. 267)

Future citizens will need to make more decisions, personal and political, regarding the impact of genetics on society. Complex, multifactorial issues such as "designer babies," gene therapy, cloning, genetic counselling, and the potential access to and use of personal genetic information, all raise ethical and scientific dilemmas. Individuals may have to decide whether to take genetics-based tests for diseases such as breast cancer and deal with the legal and emotional implications of paternity testing. The research on genetic discrimination in Australia conducted by Taylor, Treloar, Barlow-Stewart, Stranger, and Otlowski (2008) exemplifies one impact of these socioscientific issues. Of their 951 respondents who had genetic mutations but were asymptomatic for genetic disease, 10% alleged negative treatment from life insurance companies, families, health-related institutions, and employment. A year later, this research group reported the systematic verification of 13 of these alleged cases of genetic discrimination (Barlow-Stewart, Taylor, Treloar, Stranger & Otlowski, 2009). Governments worldwide are rapidly developing laws for the regulation of genetics-based research such as cloning. However, policies regarding genetic discrimination have proved harder to pin down, as exemplified by the passing of separate Genetic Information Nondiscrimination Acts in the USA in 2003, 2007, and 2008, despite the call for it originating in 1997 (National Human Genome Research Institute, 2009).

Nonhuman genetics is also contentious. Genetically modified (GM) crops have been controversial worldwide since their public release in the 1990s (Brookes & Barfoot, 2006). In July 2011, fear of GM led to Greenpeace members destroying experimental GM wheat crops developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) near Canberra (Jensen, 2011). Cormick (2005) showed that "public opinion" is itself, very complex. Several publics, each with their own views and ideological drivers behind those views, exist. Cormick (2005) reported a lack of correlation between consumers' shopping behaviours and survey statements, and that consumers want benefits for themselves, rather than for growers or the environment. Particularly relevant to this research into misconceptions about genes and DNA, was the finding that "public understanding of genetic modification, while growing, is still poor" (Cormick, 2005, p. 16). Specifically, only 31% of Australians claimed to know enough about genetic engineering to explain it to a friend and 19% stated they could explain the moving of plant genes into another plant. More than 25% incorrectly believed that most fresh fruit and vegetables sold in Australia are genetically modified: that is, subject to direct gene manipulation.

"Individuals in modern society are accessing, using, influencing and being influenced by media in ways that have not been previously observed" (Klosterman, Sadler, & Brown, 2012, p. 52). They define mass media as "tools or instruments used to convey a message and intended to reach large numbers of geographically dispersed audiences simultaneously" (p. 53), resulting in the selection of television, the Internet, radio, E-games, comics, magazines, newspapers and going to the movies for this study. Textbooks were not included. Klosterman, Sadler, and Brown (2012) add that any focus on the mass media must consider the underlying message and meaning-making that occurs in recipients of that message. This research aims to consider the messages about genes and DNA in mass media to which primary students choose to be exposed, and to explore the meaning making that recipient students create.

The mass media provide information and misinformation about science, the latter especially when nonscientists promulgate ideas about science. For example, when CSIRO's GM wheat crops were destroyed, two prominent Australian chefs wrote to a newspaper claiming that "Genetically modified wheat has no place on the menu" (Perry & Boetz, 2011). In an article full of unsubstantiated and nonscientific claims, they demonstrated a total lack of understanding and respect for scientific method.

> 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. New forms of food such as GM wheat have never
> been tested for safety. They have not undergone the kind of trial and error
> that all our naturally occurring foods have over thousands of years of
> being consumed - they are a whole new form of genetically modified life.
> And they have not been through the kind of safety testing demanded of
> new pharmaceutical products. (Perry & Boetz, 2011, para. 8-9)

From a scientific perspective, there are several gross errors in these statements, including the notion of "proof," claiming that trial and error is superior to appropriate scientific experimentation, and linking GM wheat with pharmaceuticals.

It is relatively unknown how much impact such nonscientific claims in the mass media have on people. In terms of genetics and genetic issues, understanding might be critically important in some situations. For example, jurors may face complex

information about DNA when called upon to decide a person's guilt or innocence. Depending on their age and level of schooling, adult jurors may have received little or no formal education concerning DNA. They may be ill equipped to appreciate how expensive and time-consuming DNA tests are, and whether such tests are appropriate in different criminal cases. Any information jurors have is most likely to have come from the media, of which two prevalent forms are television and the press. What might be possible outcomes of reliance on these sources of information?

Talk of a possible "CSI effect" began with Willing's *USA Today* report in August 2004, and continued in another CBS News story by Dakss (2005, March). Both stories suggested that the CSI effect resulting from regular viewing of the television (TV) crime show *CSI: Crime Scene Investigation (CSI)* is the propensity for jurors to acquit rather than convict unless there is considerable scientific evidence presented.

In 2005, to explore the possible existence of the CSI effect, the Maricopa County Attorney's Office (MCAO) surveyed 102 of Maricopa's most experienced prosecutors. In this county, prosecutors normally talk with jurors after a trial, so can directly find out what influenced the jury's decision. Although some prosecutors felt some acquittals or hung juries were due to the CSI effect, the study did not definitively show a significant increase in acquittals. However, considerable evidence *was* found for jurors wanting, expecting, and even demanding, more scientific evidence in all cases, including those that would not usually include such evidence. Amongst the evidence for terming this part of the CSI effect, the authors noted that "Jurors often ask questions about evidence using terms or language not used at trial, like 'mitochondrial DNA', 'latent prints', 'trace evidence', or 'ballistics'. Maricopa County prosecutors respond that this happens in 40% of their cases" (MCAO Survey Report, 2005, p. 6). Also 72% of prosecutors believed that jurors who watch forensics shows exert undue influence on jurors who do not, inciting them to believe that the police have not done a sufficiently thorough job in the absence of such scientific evidence.

In the MCAO study, most prosecutors said they have already altered their techniques to take account of potential jurors' television experience, by asking jurors in *voir dire* about their TV viewing, and by explaining up front why such evidence may be missing from a particular case. At the time, prosecutors noted that judges seemed to pay the notion of the CSI effect scant attention, so predictably, "As a result, 83% [of the prosecutors surveyed] agree that jury instructions should include directing jurors

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not to use outside standards like those used in forensic crime television shows when making judgments of guilt or innocence" ([MCAO], 2005, p. 10).

Mann (2006) pointed out that if the CSI effect exists, it is hardly new. He stated that the media have long influenced the criminal justice system, citing "The Perry Mason Syndrome" in which jurors expected defense attorneys to get a confession out of the "real criminal" by the end of the case, just as Perry Mason did on TV in the 1970s. Jurors also expected attorneys to go over and lean on the witness rail during questioning: a practice not sanctioned by the courts but merely an artifice used in filming to get Perry Mason and the witness in the one shot. Mann considered that

> . . . television is the most influential medium since it projects real life
> images directly into viewers' living rooms and a weekly television show
> like *CSI* will naturally make more of an impression than a once-watched
> movie or long ago read book. (Mann, 2006, p. 160)

In a different test for the CSI effect, a judge and two criminology professors (Shelton, Kim, & Barak, 2006) surveyed 1027 jurors, also finding that *CSI* viewers had higher expectations of evidence, which they termed a "tech effect." In an interview with Sheryl James (2007), Kim stated he wanted to dig deeper into the data to see if the CSI effect exists in well-educated, higher income women. However, as their overall data did not significantly show an effect of watching *CSI* on the jurors' propensity to acquit, they concluded that the CSI effect, as touted by the CBS articles, did not exist. Nonetheless, in his commentary on this study for the National Institute of Justice, USA, in 2008, Judge Shelton admitted

> It is hardly unexpected that the media grab scientific discoveries and
> quickly make them part of our popular culture. Many laypeople know –
> or think they know – more about science and technology from what they
> have learned through the media than from what they learned in school. It
> is those people who sit on juries. (Shelton, 2008, [Hypothesis and
> Discussion, para. 4-5])

Podlas (2006) surveyed 291 students with a mock scenario and considered her results debunked the antiprosecution aspect of the CSI effect though the numbers in each subgroup sample were very low. In Queensland Australia, Briody (2004) studied 75 homicide cases that included DNA evidence and 75 comparable cases that lacked DNA evidence. He found an inverse CSI effect in which jurors were more likely to

convict with DNA evidence because those cases were more likely to reach court, and "incriminating DNA evidence demonstrated a powerful influence on juries' decisions to convict" (Briody, 2004, [Abstract]).

Overall, as studies have taken varied approaches, Baskin and Sommers (2010) explained that the jury is still out regarding the ways in which these TV shows might influence both the conceptions and the actions of the public.

Consequently, in the 21st Century, with the prominence of the mass media, the burgeoning studies of genetics and associated fields of genomics and proteomics, and with difficult decisions 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. Foundational to gaining scientific understanding of any of these issues is grasping the nature of the relationship between genes and DNA and their basic functions in living things. Even teachers find this difficult (Venville & Donovan, 2005d). Prior research (Venville, Gribble, & Donovan, 2005), indicated that students are interested in genes and DNA up to four years before they are likely to be taught about it at school, but that some of their ideas are nonscientific. It is vital that educators know more about how students acquire knowledge about these topics and how misconceptions already detected by research might arise. It is therefore timely for research to consider how these two influential aspects of modern life, the mass media and genetics, intertwine, and the impact this may have on the current youth who, in just a decade, will be jurors and voters.

Scientific Literacy

Genetics is not the only scientific field that is advancing. Science and technology form a powerful marriage in which issues such as climate change, creating earthquake early warning systems, coping with pandemics such as swine flu and many more call for humans to assimilate complex information, and to make and act upon tough decisions. It is unsurprising 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). Education policy makers in many countries have been grappling with this idea, although little consensus has yet emerged concerning a definition and the process by which this may be achieved. There are, however, two areas of general agreement, the first being "that students can't be scientifically literate if they don't

know any science subject matter" and the second is that scientific literacy is for all students, not just those bound for careers in science (Roberts, 2007, p. 735).

There are two schools of thought about scientific literacy that Roberts (2007), in his extensive review of the literature to date, termed "visions." Vision 1, a traditional stance, looks at the products and processes of science itself: This is literacy *within* science. Vision 2, an 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 their selected vision. The USA has followed vision 1 with their *Project 2061: Science for All Americans* (American Association for the Advancement of Science [AAAS], 1989 and updates) whereas England has made more attempts to embrace vision 2 with their *Beyond 2000: Science Education for the Future* (Millar & Osborne, 1998). What is the situation in Australia?

Goodrum, Hackling, and Rennie (2001) produced a seminal report containing several recommendations to guide the future of Australian science education. This report 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). The report also presented an actual picture of current science education, described as "disappointing" (p. viii). The curriculum statements of the 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" (Goodrum et al. 2001, p. viii). 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 is more of a vision 1 outlook, although many Australian curriculum documents urged teachers to use situational contexts to develop the content matter, embracing vision 2. This definition permeated the Australian Science Curriculum statement (National Curriculum Board [NCB], 2009) that later emerged. It shares much with the definitions of scientific literacy within 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 differs in that both the American and English documents refer 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. Given my interest in how the media's treatment of genetics topics might influence students' understandings, this omission caught my attention, and caused me to wonder why such a specific statement was not included in the original Australian definition.

At the time of writing, the latest version of the national curriculum available was that released online in December 2011 by the Australian Curriculum, Assessment and Reporting Authority [ACARA], (ACARA v3.0, 2011). This showed a partial response to calls for inclusion of statements regarding interpreting media communications, as the Science Inquiry Skills strands for Years 9 and 10 now include "Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems" (ACARA v3.0, 2011). Secondary sources are defined as "Information that has been compiled from primary sources by a person or persons not directly involved in the study or event" (ACARA v3.0, 2011). What types of sources this statement does and does not include may not be immediately clear to some teachers. Teachers must click on greyed out content codes to find the elaborations of the content, and will not know to do so unless they download and view the guided video tour of the website. The only direct references to the media occur in these hidden elaborations. Elaborations differ for Years 9 and 10, even though the base statement on the main curriculum page is the same. Year 9 students are to consider "the methods used by scientists in studies reported in the media" whereas Year 10 students are also expected to judge "the validity of science-related media reports and how these reports might be interpreted by the public" (ACARA v3.0, 2011).

Several issues arise from this online version of the Australian Curriculum: Science. Firstly, the jargon used may be difficult for teachers to interpret and the layout makes it easy to miss important pieces of information. Secondly, the statements provide an apparently limited vision of the sources of science for consideration. Should teachers include a science report that lacks description of methods? The statements imply that teachers should ignore such a report, yet there could be benefit in discussing the rest of the science in the report, and indeed, the issue as to why the methods might not have been included. The curriculum statements seemingly apply to limited types of articles

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found in newspapers, magazines, and press releases, just those compiled directly from scientific studies. If this is indeed the intent of these statements, this constitutes an extremely narrow view of science in the media.

Specifically, there is no impetus within the curriculum statements to consider science embedded in other types of mass media, such as in entertainment television shows or movies, thus ignoring mass media sources likely to be more popular with students. For example, students may have watched the movie *Avatar* and replays of science fiction shows such as *Star Trek*, medical dramas or crime shows, all of which contain embedded science, but do not fall within the stated curriculum boundaries. England's *Beyond 2000* and USA's *Project 2061* and *National Science Education Standards* (National Research Council [NRC], 1996) documents share this criticism, as they also limit attention to science in the popular press.

Thirdly, the requirement to consider any science in the media does not begin until Year 9, yet student exposure to science in the mass media is likely long before they reach that age. For example, primary school children watch animated television shows such as *The Simpsons*, which, from websites such as "Science on The Simpsons" (www.lghs.net/ourpages/users/dburns/ScienceOnSimpsons/Clips.html) and my own viewing in relation to this doctoral research, contains considerable embedded science on a number of themes, including genetics, physics, evolution, and nuclear power. Orthia et al. (2012) investigated the science in just one episode of *The Simpsons* and found different perceptions in different people. Ideally, pursuit and development of science literacy should occur throughout a student's time in school and beyond. As the curriculum weaves the intent for students to understand the role of science in society throughout the strands, so students should consider how science is presented in society, particularly the media, from when they first encounter it.

The Australian Curriculum: Science contains statements about communicating science, with the main statements being similar year to year, specific differences found solely in the elaborations. There is encouragement to use multimodal texts and digital technologies, but only the elaborations for Years 7 and 8 raise the notion of a target audience. All statements about communication are unidirectional, dealing with science communication produced *by* students for others. For example, students are to consider target audiences they are communicating to, not themselves as a target audience for science-related content. This one-way emphasis occurs at the expense of considering how students might decode science communicated *to* them.

Specifically, there is no encouragement to examine different science-related genres in terms of the techniques used to embed and encode science, or the stereotypes of science and scientists shown. Yet much research has been conducted concerning science stereotypes, and for over 30 years "draw a scientist" tests have consistently shown that the prevailing public image of a scientist is that of an older man, with crazy white hair, wearing glasses and a white lab coat (Chambers, 1983; Whitelegg, Holliman, Carr, Scanlon, & Hodgson, 2008). Another stereotype is that of the mad scientist which Orthia (2011) considers in her examination of episodes of the TV show *Doctor Who*, also noted by Whitelegg et al. (2008). Neither is there encouragement for students to consider the possible ramifications of one audience (for example, primary school children) viewing science-related content intended for a different audience (for example, crime shows rated for mature audiences).

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. Although media literacy has become widespread in most Australian curricula, it is situated within the arts. The statements from the Australian Curriculum: Science presented here are an improvement over earlier state curricula and the first version of the national curriculum, but constitute small steps on the path to embracing science media literacy. Klosterman et al. (2012) laments that the same situation exists in traditional content disciplines in the USA, of which "science education is a prime example" (p. 52). They conducted their research in a school purported to be innovative in teachers' use of technology and the media yet were disappointed with levels of students' science media literacy. It is possible that the inclusion of statements encouraging media literacy in science in USA's *Project 2061* has not yet borne fruit.

Has science in Australian schools improved? Not yet. Performance by Year 8 Australian students on the Trends in International Mathematics and Science Study (TIMSS) has fallen compared with other countries (Thompson, Wernert, Underwood, & Nicholas, 2008), and reports still warn of a looming crisis in science education (e.g. Tytler, 2007). Goodrum, Druhan, and Abbs (2011) reported on upper secondary school science, again comparing the ideal for Australian science education with the actual; and again, the actual situation was disappointing. Their report shows that in the 1990s, nearly all upper secondary students studied at least one science, but in 2010, just half of the Year 12 students (16-17 years old) enrolled in a science subject. Data for individual subjects were only available to 2007; in that year just one quarter of the Year 12

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students studied biology, in which they received detailed education about genetics. 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.

Consequently, this research into the possible influence of the media on the development of students' understandings will create a clearer picture of the way in which students learn about genetics, a topic area that may play an important role in their future lives. The findings may stimulate the visualisation of science communication as a two-way process and encourage the application of the knowledge, understandings, and skills of media literacy to the sciences as well as to the arts. It may encourage more teachers to be involved in the process of building the science literacy of their students within a mass-media-dominated world.

Purpose and Research Questions

The purpose of the research was to explore how genetics concepts, particularly of genes and DNA, are portrayed in the mass media and how these images may influence primary students' conceptions about the nature and function of genes and DNA. The term *primary* clarifies that this work did not involve the ideas of high school students who may have had formal genetics instruction. This research explored the conceptions of students in Years 5 to 7 (aged 10-12 years) with Year 7 students classed as primary students, although in some Australian states, Year 7s are now part of middle school.

The purpose of the research comprised four specific aims. The first was to establish the degree of exposure of primary students to the mass media and to genetics concepts. Research question one (RQ1), parts a) and b), addressed this aim.

RQ1. a) What level of exposure to the mass media do primary students report?

b) What specific concepts about genetics are found in the media to which these primary students are regularly exposed?

The second aim was to explore the degree of universality of understandings and misunderstandings regarding genetics as uncovered in previous research. Research question two (RQ2), parts a) and b), addressed this aim.

RQ2. a) What is the level of primary students' conceptual understanding in genetics?

b) What misconceptions do primary students have about genetics?

The third aim was to ascertain these students' perceptions of the sources of their genetics ideas, specifically whether they acknowledged the possible influence of the mass media. Research question three (RQ3) addressed this aim.

RQ3. From where do primary students believe they have learned about genetics?

The fourth aim was to draw together the data collected about the genetics concepts presented in the media, students' use of the media, and their understandings of genetics to explore potential media influences on students' conceptions. Research question four (RQ4) addressed this aim.

RQ4. What connections can be drawn between genetics concepts in the media, participating students' reported media use, and their genetics conceptions?

The research was inclusive of mentions in the media or by students of *all* genetics-related terms including genes, DNA, chromosomes, alleles, and genomes. However, genes and DNA were by far the most prevalent, and hence the focus of this thesis.

Significance and Originality of the Study

The main role of this research was to investigate whether the ways in which the mass media presents concepts of genetics influence the development of students' genetics conceptions. The results may enable teachers to challenge media messages in the classroom, and encourage the introduction of these concepts to students earlier, in primary school, to foster the development of scientifically accurate concepts. The findings may also encourage some of the media to present genetic science in the most conceptually appropriate way. Ultimately, our future citizenry will be better equipped to make genetics related decisions based on scientific knowledge, not misconceptions.

With the importance of the role of the research established, the next question was how to conduct this research, so I searched for similar studies to provide guidance. In their monograph on the influence of television on children, Anderson and Collins (1988) pointed out that much was claimed in the popular press, but that these claims had little basis in research. Likewise, my search of the press found the claim "Everything Americans know about the legal system comes from watching *Law & Order*" several times, and always without reference to any research.

Yet this aspect has been the subject of some research (notably Surette, 1992), although his focus was on how realistic (or otherwise) the TV portrayals were of the police and the legal system. He contended, ". . . in every category—crimes, criminals, crime fighters, the

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investigation of crime, arrests, case processing, and case dispositions—the media present a world of crime and justice that is not found in reality" (Surette, 1992, pp. 245-246). Updates of such work include the research of Marsh and Melville (2009), who examined the changing nature of media portrayals of crime over time. However, their consideration of any knowledge of the justice system that the viewers may have gleaned was scant. Such criminology texts afford little or no emphasis to specific conceptual information (such as about DNA) that viewers may have gained from these TV shows, yet for young viewers, this may influence their formal education.

Anderson and Collins (1988) specifically called for research into the influence of the media, particularly entertainment television, on what they termed "children's academically relevant knowledge" (p. 6). Therefore, some twenty years later, I expected to find studies relating the influence of the media to some specific academic concepts. I found none that embraced the totality of the media viewed by the participants. Few studies had even looked at the academically relevant information embedded in entertainment media, and considered its possible influence on the children (or adults) exposed to these portrayals. Barnett et al. (2006) considered the conceptual impact on middle school students of one showing of a film, and Orthia et al. (2012) considered the capacity of adults to recognise the science in one showing of one episode of *The Simpsons*. Other available research, discussed in detail in Chapter 2 (such as Low & Durkin, 2001; Reis & Galvão, 2004), considered perceptions and the capacity of older students to debate socioscientific and ethical issues. Clearly, the situation has not changed since 1988 when Anderson and Collins completed their working paper, thus little guidance was forthcoming about how to conduct a study embracing all the media used by participants. Consequently, the study design and research tools are original.

A presentation on genetics in the mass media by Tania Christoforatou (2008) did not discuss the formation of genetics concepts, but suggested the output of researchers and the media may be filtered through the requirement to maintain financial backing for the research. She pointed out that news may be "manufactured" to lead the public to certain points of view, possibly the case with CBS news stories about the CSI effect.

Nelkin and Lindee (2004) examined the "public image" of genes and DNA in popular culture. Their interest was piqued in the 1990s when they ". . . noticed that college students in our classes drew many of their notions of heredity and DNA from movies, comic books, television dramas and sitcoms, science fiction, and other 'low

culture' sources" (p. xxv). Unlike my own, their interest did not lie in establishing beyond anecdotal evidence whether that was indeed the source of information for their students, or whether this had a definable impact on their learning and conceptions. They studied how scientific and popular cultures (including the mass media) intersect to shape the cultural meaning of the gene. They found that both genes and DNA in popular culture have symbolic meanings independent of their biological entities. Of particular interest to my research, they also pointed out that

> People act on the basis of images, sometimes without necessarily making the connection themselves between the image and the action . . . . Images of the gene in popular culture can therefore be expected to have effects even if those effects are difficult for us, with our current methods, to track. (Nelkin & Lindee, 2004, p. xxvi)

In this research, I sought to do some of the tracking to which they refer, to ascertain more precisely the effects these images of genes (and DNA) in popular culture have had on students who have viewed them.

Duncan, Rogat, and Yarden (2009) drew together the understandings of how students learn genetics to produce a learning progression for deepening students' understandings of modern genetics. Their work informed my considerations of students' conceptions and misconceptions that I uncovered in my data. Their statement that, "In a simple sense, genetics literacy involves being able to comprehend, use, or respond to information about genetic phenomena and technologies that an individual may encounter in everyday life situations" (Duncan et al. 2009, p. 657), helpfully combined the two relevant threads of genetics and scientific literacy. Their comment that, ". . . little is known about how genetics understandings develop in the elementary and middle grades" (Duncan et al. 2009, p. 659) bolstered my desire and decision to expand that knowledge through this research.

In summary, there is copious general research on media influences (but not specifically on concepts relevant to students' academic development), some research on the iconic status of genes and DNA in the media, and research on how students learn genetics, but no other research has drawn together these threads as this research has sought to do. The confluence of domains in this doctoral research was entirely original and novel, and significant in its capacity to inform the future teaching and learning of genetics.

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Chapter 2 presents a review of the literature, constructing a conceptual framework for this doctoral research. Due to the lack of specific literature describing comparable research, I cast a wider net to draw in literature that provides insight on different aspects of the study. The conceptual framework incorporates two knowledge paradigms; science and science education, in two domains; mass media influence and genetics, all situated within a background context of learning theories. Chapter 2 begins by exploring the background context, particularly, which of the multitude of learning and conceptual change theories seem most relevant to the type of learning that could occur from the mass media. Included is a rationale for the use of the term *misconceptions* in this study. Chapter 2 then examines the domain of the mass media, to show evidence of its capacity, process, nature, and extent of its influence on people. Three theories of how the mass media might exert an influence upon consumers emerge, and provide a triangulated framework for interpreting the data from this study. These three theories are the cultivation theory, social learning/cognitive theory, and the uses and gratifications theory. Specific findings regarding media exposure from other countries that pertain to aspects of this research are also summarised for later comparison. Chapter 2 continues with a review of the domain of genetics, providing a moderate background in specific genetics concepts of DNA and genes, and their treatment in school curricula. This review includes existing research into how students learn about genetics and the efficacy of current teaching approaches. Chapter 2 closes with existing evidence for links between the domains.

Chapter 3 includes the rationale for the design of this research, particularly why the design is exploratory rather than experimental. The chapter also includes the rationale for the selection and development of participants, research tools, and analytic methods. It describes the selection of regions and participants, ultimately from five schools in four geographical regions in three Australian states. Chapter 3 includes a detailed description of the development of a questionnaire to collect students' media exposure data, and semistructured interviews to collect data regarding students' genetics understandings. Chapter 3 provides detailed explanations of data manipulations such as calculations of scores, and the methods chosen to analyse and portray both quantitative and qualitative data. This section describes the descriptive quantitative analysis and visualisation of the media data in column graphs and box plots, and the use of content and discourse analysis for the qualitative genetics understandings.

Chapter 4 presents the complete data set drawn from participant students in three different Australian states, yielding a big picture of the situation. Overall patterns and trends are the focus of the findings, although the responses of some individual students are explored. This data set answers the first three research questions concerning students' media exposure, genetics understandings, and perceived sources of genetics information.

Chapter 5 presents an exploration of connections between subsets of the data in order to answer Research Question 4. It connects students' media exposure, genetics understandings, and perceived sources of genetics information with specific genetics messages embedded in examples of the mass media with which they are known to have come into contact. This chapter particularly refers to ten "TV shows of interest," being seven crime shows and three family relationship shows, which received specific attention in the media questionnaire. Throughout Chapters 4 and 5, assertions capture the plethora of findings in succinct statements.

Chapter 6 commences by summarising and drawing the findings together into 20 meta-assertions to provide a platform for discussion. The findings are compared with the literature, and the discussion revisits the three theories of media influence to propose plausible explanations for the findings.

Chapter 7 addresses the achievement of the aims of the research, the implications of these findings for the stated curriculum goal of developing scientific literacy, and generates debate concerning the placement of genetics instruction in the Australian curriculum. Chapter 7 also considers issues of trustworthiness and limitations, and future directions for the research.

The Reference section of the thesis has two subsections. The first subsection contains the scholarly references. However, as many of the media samples are referred to in tables, for ease of reading these references are numbered throughout the thesis and details provided in numerical order in the second subsection of the References. Finally, the Appendices containing supportive detailed information and copies of the research instruments and forms complete the thesis.

Chapter 2 – Literature Review

The literature review establishes a conceptual framework for this doctoral research. With no existing research into the impact of the mass media on students' understandings of any specific scientific conceptions, particularly genetics, this research fits Creswell's (2003) notion of exploiting an understudied area and searching for emergent theory. Therefore, a conceptual framework is more appropriate than a theoretical one (Rocco & Plakhotnik, 2009). The conceptual framework was created by exploring the existing research in two domains, the mass media, and genetics, within a context of knowledge and learning.

Domains and Context of the Research

Figure 2.1 presents a visual representation of the relationship between the two domains of reviewed literature and the background context.
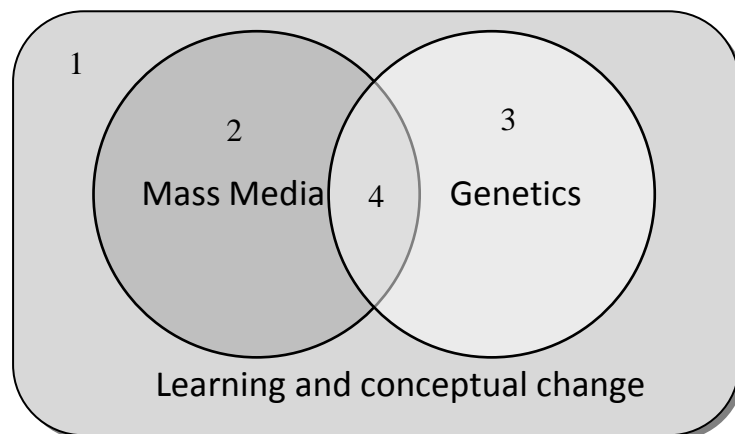
Figure 2.1. Domains and background context for the research.

The numbers in Figure 2.1 refer to the sequence in which these aspects are explored. First is a brief discussion of learning theories, including how conceptual change may occur, and when students are ready to learn. Second, discussion of the mass media domain focuses on evidence for its influence, and third, discussion of the genetics domain focuses on evidence for what students learn about genes and DNA. The chapter concludes with evidence for interrelationships between the two domains.

Aspect 1: Background Context - Learning and Conceptual Change

The fields of learning theory and conceptual change theory are both complex. Competing theories and perspectives exist in each field, and it seems probable that each has explanatory power for different scenarios. The following is a brief overview

focusing on the level and type of knowledge that students could possibly gain from the mass media, and the particular terminology used in this research.

Historically, three theories of learning have been significant over many years: behaviourism, cognitivism, and constructivism (Murphy, 2012). The earliest of these theories was behaviourism, developed in the 1920s by pioneer experimenters such as Ivan Pavlov, Edward Thorndike, and B. F. Skinner. Learners were considered passive; simply responding to stimuli (classical conditioning), which could be reinforced (operant conditioning). These ideas have persisted for over fifty years, for example, Atkins (1993) applied them to online educational contexts. In terms of this research, repeated reinforcement of ideas such as DNA's use for solving crime in many situations could potentially result in students learning this information.

Cognitivism arose in the mid 20th Century from the work of researchers such as Jean Piaget and Robert Gagne. Piaget saw learning as occurring in a series of stages, initially by sensorimotor experience, to the formal operational stage occurring from adolescence onwards (Inhelder & Piaget, 1958). Gagne (Gagne, 1985; Gagne & Driscoll, 1987) believed that there were different types and levels of learning, each of which required different types of instruction. Cognitivism focuses on the brain, on internal knowledge structures called schemas, and on the combination, extension, or alteration of schemas to accommodate new information. More recently, Ally (2004) described learning as involving memory, thinking, reflection, abstraction, motivation, and metacognition. A cognitivist view of this research predicts that information about genes and DNA observed in the mass media is accommodated into students' existing schemas. This could occur, for example, even if a student watches a TV crime show alone.

The third major theory, which takes various forms, is constructivism. Bruner's (1960, 1966) theories of constructivism overturned the traditional notion of students as "blank slates" and showed that students enter classrooms with existing ideas of their own. "Radical constructivism" (von Glasersfeld, 1993), denied the existence of an underlying reality to be known, a position I find difficult to reconcile with my view of science as both a process and a body of knowledge. Social or sociocultural constructivist theorists, such as Vygotsky (1962), contended that all learning occurs through social and cultural interactions. Vygotsky highlighted the impact of language upon learning, and the importance of discourse using scientific language appropriately. In earlier research (Donovan & Venville, 2005c; Venville, Gribble, & Donovan, 2005), students explained their reasons for thinking that objects such as the Sun, and cars,

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were alive. The problem lay with taking metaphorical use of language such as "the life cycle of a star" and "a star is born" or everyday use of language such as "my car just died" literally. Of these 14- and 15-year-old students, 60% thought the Sun was alive, and 30% thought cars were. This furthered my interest (and at times, frustration) in how everyday language, including that used in the mass media, might influence students' ideas. Mortimer, Scott, and El-Hani (2012) suggest that such heterogeneity in meaning should be expected and explained to students. For example, a documentary about stars should explain that the notion of a life cycle is metaphorical, and how and why this is not literal language when applied to stars.

An area of controversy is whether learning is an individual pursuit, occurring within the mind as the cognitivists describe, or whether it is entirely a socially constructed process. Often presented as a dipole, it may also be a continuum, with learning occurring in different ways according to circumstance. The situated cognition theories of Rogoff and Lave (1984) and Lave (1998), contended that learning is situated in the context and culture in which it occurs. For example, for classroom learning to be effective in the real world, the classroom must connect with the real world. These theories explain why I have long been a proponent of "real science" (Donovan, 1999; Donovan, 2000a, 2000b, 2000c) and of finding ways to overtly connect science in classrooms with that in the outside world. However, it is questionable how "real" the world of the mass media is to children.

Summing up these three key theories about learning, McLeod (2003) stated

> Each theoretical perspective offers benefits to designers but the perspectives must be taken into context depending upon the situation, performance goal(s), and learners. And since the context in which the learning takes place can be dynamic and multidimensional, some combination of the three learning theories and perhaps others should be considered and incorporated into the instructional design process to provide optimal learning. (p. 42)

This statement provides encouragement to consider all possible types of learning in terms of students' potentially acquiring knowledge from the mass media to which they are exposed.

Learning theory research also demonstrated that students often hold beliefs that conflict with scientific dogma and that these beliefs may be extremely tenacious.

Many studies (such as Solomon, 1983; Vosniadou, 2002) documented that for many students, there is "school science" (the answer they give the teacher) and "everyday science" (what they personally believe and apply in their everyday lives). The persistence of everyday science concepts is apparent in the documentary *A Private Universe* (1987), in which graduate students in physics, when interviewed regarding the seasons, gave answers that did not relate at all to their scientific knowledge. Consequently, science education pioneered a new field of conceptual change theories, yielding different approaches for helping students to move from everyday science to established disciplinary understandings.

Posner, Strike, Hewson, and Gertzog (1982) and Driver and Oldham (1986), put forward the classical view of conceptual change. This involved exposing these initial concepts to make both learner and teacher aware of them, and then finding ways of challenging these concepts so students would engage with them, find them wanting, and take on board the newer, more scientific concepts to which they had been exposed. Various teaching strategies were developed, an enduring example of which is the 5E model developed in the 1980s by the Biological Sciences Curriculum Study (BSCS) group led by Rodger Bybee (Bybee et al., 2006).

Hewson (1992) wrote of conceptual change as being at different levels or forms, with "change" variously meaning extinction and replacement, exchange, and extension. Some researchers only think of conceptual change in terms of problematic learning, when students hold ideas different from the norm, whereas others think of *all* learning as resulting from some form of conceptual change. Information in the mass media could feasibly result in all three forms of change in students' concepts. For example, a documentary showing DNA modification in plants could extinguish a student's idea that DNA is only present in animals and humans. Viewing compelling evidence in a family relationships TV show may exchange an erroneous belief that blood is the means for inheritance for a belief that DNA is the means for inheritance. Finally, watching many TV crime shows may extend a belief that DNA is restricted to blood to incorporate hair, saliva, fingerprints, and semen as other DNA sources.

Hewson (1992) also described two ways of thinking about the nature of knowledge, particularly, whether ideas are right or wrong. In some scenarios, truths are not absolute and apply to only some situations and contexts. For example, Newton's Laws apply to a wide range of phenomena, but fail when considering the very fast (requiring consideration of relativity) and the very small (requiring quantum mechanics).

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However, in other scenarios, truths appear more absolute, such as genes are made of DNA, and correctly knowing these facts are important for further growth of knowledge. This latter scenario will be the likely focus of genetics information that students may acquire from the mass media.

Four different perspectives on conceptual change have arisen, differing mainly in the level of knowledge considered for change. Different groups of scholars have pursued each vigorously, but Duit and Treagust (2012) noted that no one perspective covers all. They used the past work of Venville and Treagust (1998) to support this contention, pointing out that viewing conceptual change from four theoretical perspectives, meant each perspective raised issues that the others did not. Following is a brief review of the four perspectives.

Chi and Roscoe (2002) viewed knowledge at the broadest level, by considering that children assign naive concepts to inappropriate ontological categories such as material substance instead of constraint-based processes. They saw conceptual change as being an ontological shift. Relevant to this research, would be the need to change the concept of gene from an inherited object (material substance) to a biochemical process. However, in this research, my concern is more that young students may come to recognise a gene as an inherited object without also understanding that it is made of DNA: necessary knowledge for them to make the ontological shift to biochemical process in the future.

Carey (1985) narrowed the view slightly to theory level, regarding children's naïve concepts as connecting up to form intuitive theories with explanatory power, and seeing conceptual change as a theory shift. Vosniadou's (1994) framework theory blends these two perspectives, considering ontological commitments influence the assimilation of new ideas into an existing framework. Conceptual change thus requires a restructuring of that framework. Vosniadou (2012) points out that this is more likely to be a slow process rather than the sudden, transformative change predicted from classical theories of conceptual change. However, this research is not dealing primarily with knowledge at a theory level, other than a theory of inheritance. This theory involves knowing that some particles, which students might name as chromosomes, DNA, or genes in a genetic theory of inheritance, pass from parent to offspring, bringing about family resemblance. Our prior research (Venville & Donovan, 2005c) and that of others (Solomon, Johnson, Zaitchik, & Carey, 1996; Springer & Keil, 1989; Springer, 1999)

showed that most children had acquired a theory of inheritance by age seven, so I expect the 10-12 year old students in this research to have a theory of inheritance.

Özdemir and Clark (2007) viewed these three perspectives as representing a position of seeing knowledge-as-theory, in opposition to the fourth perspective of knowledge-as-elements. This view builds on diSessa's (1993) work, in which knowledge elements or sub concepts are quasi-independent and loosely connected, and termed phenomenological primitives or p-prims. From this perspective, conceptual change involves the reorganisation of p-prims over time. As information about genetics in the mass media is likely to be fragmentary in nature and in its mode of acquisition, this perspective of knowledge-as-elements is likely to be most applicable to this research.

Knowledge

Knowledge is a word with many nuances of meaning and little philosophical agreement. Even within the Oxford Dictionary, definitions vary from "awareness or familiarity" and "facts, information, and skills acquired through experience or education" to "information stored on a computer" and "the sum of what is known" (Pearsall & Keir, 2012, para. 1 & 2). From a critical thinking perspective as espoused by Jacobs and Cleveland (1999), "Conceptual knowledge is the organization of ideas by the power of mind" (para. 11), and, "We experience first and understand later" (para. 29). Cognitivists such as Paul (1995) view knowledge as being built in a series of stages, beginning with *information* gained from different types of experience (observation, education, other's opinions) entering the mind as *ideas*, and transitioning through thought and comprehension to generalised ideas called *concepts*, ending up as *knowledge* once organised and justified. Yet social constructivists such as Tobin and Tippens (1993) view all learning as socially mediated, knowledge resulting from a social process in which experience is made sense of in terms of extant knowledge.

This research focuses on information about genetics that students may acquire vicariously, via the mass media. This is social in that the mass media models social situations, but may or may not result in students actively discussing these vicarious experiences with others. From a cognitive point of view, students may express a range of knowledge in their interviews, from disconnected *ideas* to generalised *conceptions* (and possibly *misconceptions* as far as scientific accuracy is concerned); yet others may represent their actual *knowledge*, where they have achieved understanding and a clear, justifiable grasp of the subject. However, for convenience, and given that the

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definitions of knowledge may encompass mere awareness to true comprehension, in this research, the word *knowledge* represents the gamut of student interview responses.

Conceptions and Misconceptions

A conception (or concept) is an abstract idea defined in the Oxford Dictionary as

Philosophy: an idea or mental image which corresponds to some distinct entity or class of entities, or to its essential features, or determines the application of a term (especially a predicate), and thus plays a part in the use of reason or language. (Pearsall & Keir, 2012, para. 5)

In this research, students' conceptual knowledge about genetics may relate to all aspects of this definition. For example, having seen images of DNA molecules as a double helix, students may have a concept or mental image of DNA as a "twisty ladder" (Venville & Donovan, 2006a). Observing blood as a source of DNA could lead students to an erroneous generalisation that DNA is blood and to reasoning further, that like blood, DNA may be donated.

A necessary decision in this research was what to call erroneous beliefs, those that do not match scientific dogma. The literature concerning conceptions and misconceptions is extensive offering many synonyms for *misconceptions* (Murphy & Mason, 2006). These include alternate/alternative conceptions, alternate/alternative [conceptual] frameworks, preconceptions, prior conceptions, naïve conceptions, naïve beliefs, naïve theories, minitheories, intuitive beliefs, intuitive knowledge, intuitive science, children's science, and learners' science. Notably, "Despite nuances in meaning that differentiate them" (Murphy & Mason, 2006, p. 307), Taber (2009, para. 3), notes, ". . . there is no clear consensus in the way these terms are used across studies by different authors."

The decision to use *misconceptions* rather than one of the synonyms in this research relied on several related aspects, the first of which was the ideological stance of the researcher. I come to this field of educational research as a scientist. This is more than just dealing with science topics such as genes and DNA; it is also a way of thinking that has been deeply instilled. It permeates my vision of what constitutes research, and although I believe science is more than facts, nonetheless, accurate facts are still an important consideration for a scientist. The Latin word *scientia* means knowledge. I hold a vision of science that resonates with Hewson's (1992) scenario of science revealing truth about the natural world.

Secondly, young children lack specific scientific knowledge about genetics. It is unlikely that young children would form intuitive ideas about DNA and genes from direct experience in everyday activities as might occur with such concepts as floating and sinking, or a flat earth. Young children are also not fledgling geneticists as they have not yet been enculturated into scientific ways of thinking and speaking about genetics. They use their explanations inconsistently and these have poor explanatory power (Venville, Gribble, & Donovan, 2005). For these reasons the terms intuitive science, children's science, learners' science, and naïve conceptions were not applicable to this research.

Thirdly, the use of *alternate* is grammatically incorrect, meaning "to occur in turn repeatedly" (Pearsall & Keir, 2012, para. 1). *Alternative* is grammatically appropriate, but refers to "another possibility or choice" or "activities that depart from or challenge traditional norms" (Pearsall & Keir, 2012, para. 1 & 2). Such definitions imply that the choice is equal in weight, inappropriate when comparing scientific explanations with the nonscientific explanations offered by children. As this research is interdisciplinary and involving the mass media, it is preferable to avoid a term that could be misinterpreted to mean that the ideas of children carry as much weight as the ideas of scientists in explaining the natural world.

Chi and Roscoe (2002, p. 3) differentiated between two types of naïve knowledge. They used *preconceptions* for naïve knowledge that is revised moderately easily through instruction, and *misconceptions* for that which is more robust and highly resistant to change. In our prior research (Donovan & Venville, 2005b; Venville & Donovan, 2007); we had some success in changing the "misconceptions" we identified through targeted instruction, so a case could be made for using preconceptions rather than misconceptions. That said, there is no agreed educational definition of the term *preconception*, and Vosniadou (2012) defines these terms differently. She uses preconceptions for children's ideas developed from everyday experience *prior to* exposure to school science, and misconceptions for students' synthesised models *after* exposure to school science. However, she does not consider the possibility that students' exposure to science from sources other than school may also alter preconceptions into misconceptions. In particular, she argues that misconceptions arise "when students are exposed to scientific explanation without adequate instruction" (Vosniadou, 2012, p. 124). In this research, students are likely to be exposed to scientific explanation, of dubious quality, in the mass media, without any instruction.

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Consequently, *misconception* appears to be an appropriate term for nonscientific ideas about genes and DNA held by students in this research.

Finally, in this research the definition of misconception adheres most closely with that of Pines and West (1983) in being a representation that does not align with established disciplinary knowledge. The term misconception is applied to ideas that are completely opposed to disciplinary knowledge, and to partly inaccurate or incomplete conceptions. Absence of specific knowledge is not considered a misconception.

When are Students Ready to Learn?

This section considers the issue of student readiness, of relevance to the timing of inclusion of ideas about genetics in the curriculum. The work of Piaget and Inhelder (1974; 1976) concerning the change from concrete operations to formal operational thought at about age 14 is well known and widely accepted, especially by curriculum developers, although not always consistently applied. Students encounter some entirely abstract concepts such as "energy" in primary schools in some curricula, long before students reach Piaget's concrete to formal transition stage.

A growing body of work (e.g. Hirsch, 2006; Keil, 1984; Murphy, 2012; Stone, 1996; Willingham, 2008) vigorously questions whether students are held back by the absolute acceptance of Piaget's views. Any research is likely to be of limited currency, applicable to the time and locale of the test subjects. Much of Piaget's experimental work occurred in the early part of the 20th Century when students and their life experiences were very different from now. It is plausible that modern students are able to process some concepts at younger ages than were their earlier counterparts.

Research has shown that both the nature of the task and students' prior experiences are important. Willingham (2008), says

> If a child, or even the whole class, does not understand something, you should not assume that the task you posed was not developmentally appropriate. Maybe the students are missing the necessary background knowledge. Or maybe a different presentation of the same material would make it easier to understand. (p. 39)

Hirsch (2006) suggests that assumed background knowledge may be missing due to cultural differences. Consequently, exposing students to background knowledge should be an integral part of appropriate practice. To omit such exposure means that students

lack sufficient contextual information to make sense of what they read, view, and absorb from the world around them. Willingham (2006) contends that knowledge helps at all stages of learning and to deprive students of such knowledge is to deprive them of their maximum capacity to learn. Of relevance to this doctoral research, Collins (1982) also contends that a broad knowledge base is a prerequisite to understanding what is on TV.

How might students shift from concrete to abstract thinking (Piaget & Inhelder, 1974, 1976) without exposure to complex ideas earlier? This challenge was met with considerable success by some researchers such as Adey and Shayer (1994) in their development of Cognitive Acceleration through Science Education (CASE) in the UK. Piaget (2001) himself later wrote of children doing things and reflecting on what happened, until ultimately, they move from one cognitive stage to the next, processes he termed reflecting abstraction and empirical abstraction. Murphy (2012) supports Vygotsky's contention that learning leads development, so teachers should always be challenging students rather than waiting for them to reach a predetermined developmental stage. Unfortunately, curricula do not always reflect these insights, and rarely give children opportunity to engage with concepts beyond their current level of thinking or to revisit them periodically. Willingham (2008) 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. (p. 39)

A concern is that as educators, we are leaving it too late to introduce genetics concepts. By Years 9 or 10, students *have* already learned about DNA elsewhere, but, lacking enough background, may not have learned accurately. In addition, because it is not new to them, we have lost the chance to excite them about the topic. In previous research, I experienced how excited and eager Years 2 and 5 students were to learn about genes and DNA, asking endless questions. Sadly, by Year 9, the attitude was decidedly "ho-hum, so what" and it was almost impossible to rouse their interest and enthusiasm for learning more, despite these students holding some of the least scientifically accurate beliefs I encountered (Donovan & Venville, 2005c; Venville & Donovan, 2005a). My concerns are supported by the findings of Tytler and Osborne (2012), who reviewed eight studies that collectively showed that boys and girls are highly interested in science at age 10, and that aspirations for (or against) a career in

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science are formed by age 13 or 14. These aspirations are influenced by their life-world experiences, their enjoyment of science, perceptions of their ability in science, and exposure to inspirational science teachers. These findings highlight the importance of primary science programs, which should capture their interest when it is at its height by exploring science about which they are excited.

To give students opportunity to move from intuitive to cognitive understanding, Bruner suggested a spiral curriculum. He stated, "A curriculum as it develops should revisit these basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them" (Bruner, 1960, p. 13). Reigeluth and Stein (1983) extended this idea with their elaboration model of instructional design, requiring multiple presentations of material from general to detailed and from simple to complex. This approach should allow for deeper learning than the one-time method characteristic of the crowded curricula prevalent in high schools in the late 1970s and 1980s, and apparently still continuing today.

Summary of the Background Context

The previous section detailed three major theories about knowledge and learning; provided a rationale for describing students' nonscientific ideas as misconceptions; and dealt with the issue of student readiness to encounter the topics of genes and DNA in primary school. The next section explores the first domain of this research, the mass media, and particularly, three theories by which the mass media may exert an influence on its audience.

Aspect 2: First Domain - Possible Influence of the Mass Media

Four key questions explored in this section are firstly, do the mass media influence people? Secondly, if so, how may mass media exert this influence? Thirdly, what is the nature of the influence – in particular, can the mass media change the knowledge of the audience? Fourthly, what is the extent of the influence?

Do the Mass Media Influence People?

Historical political perspectives.

From McQuail's (1979) summary of 80 years and 3 phases of research on the question of mass media influence, the answer would be yes—no—yes. In phase 1 (1900 to late 1930s), the great attraction of the popular press, cinema and radio gave

rise to the assumption that the mass media wielded considerable power to shape opinion and belief, change habits, actively mould behaviour and impose political systems even against resistance. In phase 2 (1940 to early 1960s), McQuail (1979) claims that scientific investigation of radio, film, and print overturned the assumption of phase 1, indicating that the media were unlikely to be major contributors to change of opinions, attitudes or behaviour or to be a direct cause of crime or aggression. However, this relied on relatively few but much cited studies tackling a narrow range of questions. Influential researchers such as Klapper (1960) summed up these studies as demonstrating that mass communication is not a sufficient cause of audience effects, but functions through a nexus of mediating factors.

The third phase (mid 1960s and continuing), reconsidered the "no effect" conclusion, especially with the new medium of television. McQuail (1979) concluded that the evidence indicates that the mass media can attract and direct attention to problems, solutions, or people and/or divert attention away from rivals. It can confer status and confirm legitimacy; be a channel for persuasion and mobilisation; help to create and maintain certain kinds of publics; be a vehicle for psychic rewards and gratifications in that it can divert, amuse and flatter; and finally; be a cost effective means of communication in society. Noticeably absent is any comment regarding mass media's potential for transmitting concepts learned by the audience.

Educational debates.

Acceptance of media influence and the rise of television prompted a flowering of educational research into the influence of the mass media during the 1980s and 1990s. This research featured a debate about whether media could affect learning, with Clark (1983) stating that "media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (p. 445) and reiterating his position in 1994. Kozma (1994), one of several researchers contesting Clark's position, argued that the media could influence learning, but that research had failed to establish a *causal* connection because it had been inappropriately constrained. He hypothesised how different types of media *might* influence learning, for example, print's stability allows the learner to skip ahead or review, whereas television's transience sets the pace for the learner, but I found no subsequent research specifically testing these ideas.

The debate was essentially about the use of new media such as computers in classrooms, not about the effects of the mass media on learning. Only one article was

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found directly relating Clark's and Kozma's opposing positions to the *mass* media. Walma van der Molen and van der Voort (1998) reported their experimental study on children's recall of the news from television reports compared with three different print versions. They found for Kozma's argument, in that "The results of a cued recall test indicated that children who watched the news on television remembered the stories better than children who read one of the three print versions, regardless of their level of reading proficiency" (p. 39). This finding predicts students in this doctoral study will recall genetic information from television and print, TV having more impact.

The current opinion is that the mass media definitely influences people, with television being "an effective and pervasive teacher of children and youth" (Slaby, Barham, Eron, & Wilcox, 1994, p. 451). The stated intent of McQuail's (1979) discussion was to clarify the important consequences of the mass media for all levels of society and to question, "*Who* has access to the use of this power" (p. 90). However, in this doctoral study, the interest was more whether and how the mass media might exert an influence, and the nature of that influence, than in who might be the driver behind that influence.

How Might the Mass Media Exert an Influence?

Three main theories are propounded by which the mass media may exert its influence – cultivation theory; social learning/cognitive theory; and uses and gratifications theory. These theories differ more in emphasis than in perspective, and are not mutually exclusive: realistically, all three theories have explanatory power for different situations and for different aspects of one situation. A fourth theory, the agenda-setting theory, addresses the ideological motivation of the media producer rather than the effect of the media on the recipient. It seems unlikely that entertainment TV producers are ideologically driven to plant misleading information deliberately to deceive students, so the agenda-setting theory is not considered here.

1. Cultivation theory.

Espoused by Gerbner, Gross, Morgan, and Signorielli (1980, 1982, 1986), the cultivation theory asserts that heavy television viewing cultivates perceptions of the world that are consistent with television's portrayals. This theory emphasises the *amount of time* spent watching TV, rather than its specific content. It also assumes that heavy viewers are less discriminating about what they watch, engage in habitual viewing, and experience repetitive content. Heavy viewers may have fewer sources of

ideas than light viewers who presumably have other activities that displace viewing time. Gerbner went so far as to describe TV as a "key member of the family, the one who tells the stories most of the time" (Gerbner et al. 1980, p. 14). However, cultivation also depends on TV being perceived as realistic, which depends both on the nature of the show and the person watching it. For example, animations are clearly not "real" and yet audiences empathise with the characters. Media researchers are yet to complete work examining the effects on audiences of the explosive growth of so-called "reality TV."

In later expansion of the theory, Gerbner et al. (1994) maintained that cultivation is but one way to explain media influence, not the only way. They predicted that recent generations who are growing up with TV will be even more enculturated to believe that it represents the real world than previous generations as "lessons" learned repeatedly from TV can affect one's worldview. Van Evra (2004) also speaks of a "drip effect" in which knowledge and information can be picked up even if one is viewing television primarily for entertainment. This incidental type of learning was the focus of this doctoral research as my expectation was that relatively few students are likely to have actively sought information about genes and DNA.

Applying the cultivation theory to this doctoral research also suggests that the more often students are exposed to certain messages about genes and DNA, the more likely they are to give answers to questions about these concepts that are consistent with the messages they have seen. Thus, students frequently exposed to the idea that DNA only exists for solving crime, are likely to give that answer when asked about DNA's function. The cultivation theory also predicts that heavy viewers of television crime shows are more likely to give these answers than are light viewers.

   2. Social learning/social cognitive theory.

The second theory concerning the influence of the mass media builds on Bandura's social learning theory, which arose in the 1960s and expanded into social cognitive theory (Bandura, 1994). This theory contends that learning results from observing and modelling the behaviours, attitudes, and emotional reactions of others, and that the specific *content* viewed is more influential than the amount of viewing. Bandura (1977) pointed out that it would be slow and unsafe to rely only on learning from one's own actions, and that learning from others is more efficient.

Perhaps the most common and pervasive examples of social learning situations are television commercials which suggest that using a particular product will make us popular and gain the attention and admiration of attractive people. If these commercials attract the viewer's *attention*, and are sufficiently catchy for the information to be *retained*, the viewer is likely to *model* the behaviour and buy the product, as long as they have been *motivated* to do so by seeing a valued outcome. This example highlights the four key subprocesses underpinning Bandura's (1977) theory – attention, retention, modelling (behaviour production) and motivation.

Bandura's (1994) social cognitive theory is a possible explanation of the process by which viewers might learn aggression from media violence. Although the theory has limitations at the gross level (e.g. does media violence cause aggression or do children predisposed to aggression choose to watch more media violence?), it explains more defined learning situations such as the influence of commercials, especially as they are specifically designed to capture attention, be retained and be motivating to the viewer.

Schmidt and Vandewater (2008) reviewed research on links between various types of electronic media and general cognitive skills of school-aged children and adolescents. They agreed with Bandura (1977, 1994), finding that viewing educational TV is linked positively with academic achievement, and viewing entertainment TV is linked negatively with achievement. They linked specific skills such as visual spatial skills to video games, but little mention was made of particular academic knowledge or conceptual development.

The social cognitive theory emphasises *what* people see, so in this doctoral study, this theory predicts that participating students' knowledge about genes and DNA should model the specific media content about genes and DNA that they have seen.

3.   *Uses and gratifications theory.*

The uses and gratifications theory focuses on users' motivations and needs, their media preferences, the use they make of the mass media, and their patterns of use. A key researcher in the development of this field was Rubin (1984, 1985, and 1994) and he contended that whereas motives for viewing vary with content and among viewers, both children and adults use media content to satisfy personal needs and wants. However, these needs and wants may vary over time, so, for example, the use of television for excitement decreases between the ages of 9 and 17 (Rubin, 1985). This encompasses the age groups within this research.

Comstock and Scharrer (1999) concluded that the available data at that time showed three broad categories of motivation for viewing ranked in importance:

1. Escape – to relax, enjoy, change mood, escape from pressures.
2. Self-evaluation – how well do I measure up, comparing to others.
3. Information-seeking – to keep up with the medium, to see how television treats various topics.

Rubin (1984) and Rubin and Perse (1987) distinguished between viewers who actively select certain programs and view purposefully, and those who watch nonselectively and ritualistically. They found that the former group (selective viewers) value TV less as a medium than the latter group (ritualistic viewers). They also realised that the same person could be selective about some programs and nonselective about others, depending upon time, background, and situation. Comstock and Scharrer (1999) expanded this to state that in ritualistic viewing, the medium takes precedence over content, the motivation is to watch TV and then choose the best available program to do so. In selective viewing, the desire is to watch a particular program (especially specific interests such as sports, news) so the selective viewer turns the medium off if that program is unavailable.

Metzger and Flanagin (2002) compared old and new technologies in terms of active and passive usage. They found that traditional media such as print and television are used more passively for entertainment and relaxation, whereas new technologies such as the Internet and E-games are used more actively with goals that are more specific. It will be interesting to see if this changes in the future, as more generations grow up with these "new" technologies and they are no longer new, and as social media, such as Facebook, become ubiquitous. In this research, the uses and gratifications theory offers explanatory power for students' preferences (gratification) and choices between old and new media (usage).

Drawing these three theories together.

The three theories just described formed a framework that guided the selection of specific questions to ask the participating students. It was necessary to ask *how much media* was used (amount as per cultivation theory), *what media* was used (content as per social learning theory), and about *favourite* shows and characters (preferences as per uses and gratifications theory). The three theories collectively offer explanatory power for the findings of this doctoral research.

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What is the Nature of the Influence of the Mass Media?

Research indicates that the mass media may influence attitudes, beliefs, opinions, knowledge, and behaviour. It is beyond the scope of this thesis to examine all of these. Much of the massive body of media literature is devoted to topics such as self-esteem, body image, violence, and risk-taking, not directly relevant to this doctoral study. Most relevant to students' understandings of genetics is any research that implicates the mass media as influencing knowledge acquisition.

Early research.

According to *TV Facts* (Steinberg, 1986), the percentage of homes in the USA with televisions increased from 9-98% from 1950-1978. Given this substantial increase in TV ownership, it is unsurprising that the golden age of research into television and its effects was the 1980s and 1990s, so it is important to review some of the classic findings of that time. However, Anderson and Collins (1988) were scathing about the methods used in some of the early research, and called for more scientific methods and greater consistency in reporting of results. Similarly, Kozma (1994, para. 2) argued there was "a certain urgency" to uncovering the relationships between the media and learning to yield improved theories, research and instructional designs. He feared that otherwise the new technology would be

> . . . used primarily for interactive soap operas and online purchases of merchandise. Its educational uses may be driven primarily by benevolent movie moguls who design "edutainment" products whose contribution to learning may be minimal. (Kozma, 1994, para.2)

Those calls went largely unheeded, with the notable exception of Rideout, Foehr, Roberts, and Brodie who began their detailed media use questionnaires in 1999, continued by the first three authors at five-yearly intervals. I have chosen to include here only the early research considered methodologically sound by Anderson and Collins (1988).

The focus in the 1980s was on children learning to read and acquiring language, so much research occurred into TV shows such as *Sesame Street*. Some researchers, such as Rice (1983), saw the media as having a positive influence. Television that uses appropriate formats for young children such as redundancy, repetition and visual salience, can be a source of new words, similar to parents reading books to their children (Lemish & Rice, 1986). Naigles and Mayeux (2001) concurred that TV is a

source of new vocabulary, but cautioned that it does not facilitate the learning of grammar and there is no evidence it could ever replace natural language input in teaching children language. They expressed this metaphorically as, "If the environmental influences on child language acquisition were thought of as a four-course dinner, then the place of television input is as one of the options on the dessert plate" (Naigles & Mayeux, 2001, p. 150).

Not all were positive; others such as Doerken (1983) noted that television language includes much doublespeak and contradiction (e.g. dye your hair for a natural look), slang, street language, superlatives and exaggeration. In a landmark study requiring access to some remote Canadian towns, Corteen and Williams (1986) examined a community before and after TV was introduced, and found that TV did not displace well-established reading skills, but does slow the acquisition of these skills. One study (California Assessment Program [CAP], 1988) found an inverse relationship between the amount of television viewed and general achievement in history, social science, and science but did not examine specific concepts. Anderson and Collins (1988, p. 7) noted that, "When national achievement test scores decline, television is blamed. When they rise, television has no role," showing that the prevailing frame of the role of TV was as a negative influence.

Comstock and Scharrer (1999) noted that television socialises children to prefer nondemanding content, and Postman (1985) commented that television's style of learning is hostile to school or book learning because it requires no prerequisite knowledge, undermines the importance of sequential knowledge acquisition and concentrates on storytelling rather than reasoned argument. Van Evra (2004) commented on the blurring of many of the features of television and school over time. Over my extended teaching career, I have noticed the influx into the classroom of resources and strategies that motivate and engage students in much the same way as television programs do. This may cater to students who require some level of entertainment in order to maintain an investment of mental effort.

Other findings still current include those of Gibbons, Anderson, Smith, Field, and Fischer (1986) that action (visuals) are generally better remembered than utterances, especially in younger children. Collins (1982) surmised that children might not achieve full understanding of what they see on TV until 8th Grade because they need to develop a knowledge base in order to make sense of what they see. Thus, Year 5 students may remember less about genes and DNA than older students may, as DNA is uttered more

than seen, and any of the Years 5-7 students may lack sufficient knowledge to fully understand what they see on television about genes and DNA.

This body of research indicates that this doctoral study may find that students acquire language about genes and DNA from their exposure to the mass media, particularly from entertaining shows that engage them. However, despite being entertained, they may not necessarily achieve sufficient understanding to use this language appropriately and accurately in terms of its scientific meaning.

Recent research.

It appears that Kozma's (1994) concerns about television and learning has not given rise to much research attempting to expose *whether* and *how* students may learn specific *concepts* from the media. The closest comparable research located was that considering the response of viewers to a single viewing of a science fiction film or television show. Barnett et al. (2006) exposed middle school students to a single viewing of *The Core*, and found it negatively impacted their earth science understandings. Specifically, the scientific credibility of the main character, the character getting some of the science correct, and the use of scientific-sounding dialogue were the keys in students predicating what they had seen in the movie over what they had experienced in class. Barnett et al. (2006) applied their findings to the process of conceptual change, and pointed out how movie images are visually appealing, easily understood, and often hook in to students' existing understandings. This gives them high status in the students' minds, explaining why the movie ideas become an important part of students' scientific understandings and explanations. Barnett et al. (2006) acknowledged the limitation of their study relying on a single viewing, and called for studies with repeated viewing, as in this doctoral research.

Orthia et al. (2012) exposed adults to a single viewing of an episode of *The Simpsons*, and found a range of responses to the science content in the show, from noticing very little science to believing it was all about science. These researchers were not primarily looking for influence on viewers' conceptual knowledge.

In terms of the ages of participants in this research and the possible influence of repeated viewing, of particular relevance was work based in Western Australia with students from Years 1, 3, 5, and 7, (ages 5-12 years) conducted by Low and Durkin (2001). Although reference was made to "concepts" the research actually assessed children's perceptions and beliefs about police activities, with the general finding that

what children saw on TV (i.e. an overrepresentation of using guns, breaking down doors and high speed chases and an underrepresentation of routine tasks such as paperwork) coloured their perceptions of what occurs in everyday life. However, this was more applicable to the younger children; the older ones realised police must do some paperwork, though still underestimated the real amount. This study made only simple measures of students' exposure to crime shows, and their beliefs concerning the source of their information regarding police work.

In 2001, Koshi Dhingra gave a preliminary report on her research into whether TV can teach science, reported more fully in 2003. Noting a lack of research in this field, her exploratory research was with 10th and 11th Grade students, and examined how their thinking about the nature of science and scientists was mediated by four different TV genres: documentary, magazine-format, news, and drama (*The X Files*). She found that such viewing motivated students of those ages to think critically and to question, and that discussing TV shows with teachers positively changed classroom relationships. No longer was the teacher the expert and the student the ignorant one; they were discussing something they had both seen, and therefore had in common. Her study broke new ground by including an entertainment genre, but did not specifically examine students' academically relevant knowledge or conceptual development as this doctoral research seeks to do. Nonetheless, her statement (Dhingra, 2003, p. 234) that it is important for educators to recognise that students bring ideas about the nature of science and scientists from television into the classroom, resonated with my concern that younger students may also bring ideas from TV into class. However, by 2012, Dhingra's interest had moved to stories connecting to citizen science, children's educational programming, documentaries, and entertainment education stories. She suggested, "Learning via television may be a unique cognitive phenomenon" (Dhingra, 2012, p. 1143), but, while calling for more research, she also noted the complexity and need to account for a number of influencing factors in such research. She reiterated TV's power as a science communicator and suggested that educators, science experts, and TV practitioners should join forces to improve communication of socially robust science.

Like Dhingra, Klosterman et al. (2012) noted a lack of research into the influence of what they term "NIMM" (noninstructional mass media). This refers to media not specifically created for use in classrooms, but for public information or entertainment. However, their research interest was in how *teachers* might use NIMM in their classrooms to provoke discussion of socioscientific and sustainability issues, rather

than in how NIMM viewed by choice at home might influence student conceptions about essential scientific knowledge required for academic progress.

Research in Portugal by Reis and Galvão (2004), probed the ideas of 17-year-olds in terms of the influence the mass media may have had on their conceptions of scientists, and socioscientific issues. This built on earlier work by researchers such as Aikenhead (1988) whose 18-year-old respondents claimed that the media was their major source (73%) of information about such issues and the work of scientists. The teaching of socioscientific issues is a growing field of science education. However, published research, such as the 14 chapters in Zeidler's (2003) book on moral reasoning and socioscientific issues in science education, seldom addresses specific fundamental concepts that students will encounter in school science. Most researchers in this field deal with students at or near the end of their schooling; only one chapter in Zeidler's (2003) book considered elementary (5th Grade) students. The main aim of such a book is to explore how best to produce scientifically-literate citizens able to take their place in a society in which, as described in Chapter 1, genetics, genomics, and proteomics is set to play a major part. This is also an aim of this research, but the specific interest here is in media influence on the fundamental scientific conceptions of younger students.

Recent Australian research considered the influence of TV hospital shows such as *House, Grey's Anatomy,* and *Scrubs*, on undergraduate medical students (Weaver & Wilson, 2011). They found that students discussed issues arising on these shows with family and friends and had high recall of ethical topics portrayed on these shows. However, the students also believed that the TV shows portrayed high standards of professionalism, yet analysis shows that professional behaviour is often sacrificed for dramatic effect. This research indicates that such shows may influence medical students more than they realise, but again, this research did not specifically consider the influence of these TV shows on students' academically relevant knowledge such as anatomy and physiology.

A possible reason for the paucity of research in the field of media influence on children's cognitive, emotional, and social development is suggested by Clay (2003, p. 40) who noted that for years, psychologists wishing to undertake such research were refused funding, with funders quoted as saying, "We're not going to pay someone to study kids' video games. That's silly." It was only in the mid 2000s that large-scale funding began to become available for this type of research. Aubusson, Griffin, and

Kearney (2012) review many of these studies in their considerations of science learning in digital worlds. The focus of this body of research is on games and conversation spaces, and the development of scientific skills and science media literacy skills predominate. The review did not mention students' development of specific science concepts such as genetics.

One body of research indirectly indicates that knowledge acquisition results from repetitive exposure. Such research involves the evaluation of persuasion campaigns, also called public service, public education, or social marketing campaigns, which aim to change behaviour. However, both early research (for example, on seatbelt usage by Robertson et al. in 1974) and recent research (for example, *Slip, Slop, Slap* and its follow-ups to promote skin cancer prevention by Cancer Council Australia in 2009), indicate that the main result is knowledge acquisition rather than behavioural change. Evaluators consider recall of the message a success, although Cancer Council Australia (2009) stated that, "Adolescents spend more time in the sun than any other group. While they have been shown to have a high level of knowledge on the dangers of sun exposure, they engage in relatively few sun protection behaviours" (p. 45). Although hats are now common uniform policy in schools, another study showed that hat *wearing* is the least frequent sun protection behaviour and is very resistant to change (Smith, Ferguson, McKenzie, Bauman, & Vita, 2002, p. 58).

Van Evra (2004) summed up the research on public education campaigns by concluding that, "The actual impact on behavior of this use of advertising, however, is inconsistent. Changing knowledge about a topic is far easier than changing behavior in that area" (p. 127). Behaviour change usually involves breaking a habit, and even after years of research into methods of breaking habits such as interference, rewards, and implementation intention, research shows that the stronger the habit, the harder it is to break (Webb, Sheeran, & Luszczynska, 2009). Dhingra (2012) noted that some governments have responded to this lack of effectiveness of persuasion campaigns in changing behaviour by collaborating with television producers to produce more subtle, and hopefully effective, strategies. Entertainment education (EE) involves embedding desired messages, such as the designated driver concept, in episodes of many different TV shows, apparently resulting in increased compliance as well as increased awareness (knowledge) of the concept. Dhingra (2012) noted reports of effectiveness of similar EE strategies in South Africa and the concept is spreading into Kenya, Tanzania, and India.

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In her meta-analysis of research in the field of TV and child development, Van Evra (2004) offered very little about science, beyond reporting the finding of one study that students aged 8-9 and 14-15 years, particularly girls, considered science on television to be beneficial. No research that considered academic learning in science was cited in Van Evra's (2004) review, nor did any appear in a later, similarly seminal work that summarised 50 years of research into the effect of television on children (Pecora, Murray, & Wartella, 2007). Yet Anderson and Collins (1988) hypothesised that students might gain "academically relevant information" from entertainment TV, and called for research into this field (pp. 6, 40). Beyond the examples discussed here, none of which considered the total viewing of entertainment media related to conceptual learning, I found no other literature considering conceptual learning in any field related to entertainment media such as history, geography, or science. Personal communication with Dan Anderson (email, April 27, 2011) confirmed this call has remained unanswered until this doctoral research.

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

Nelkin and Lindee (2004) attest to the embedding of genetics concepts in the mass media. They commented that DNA and genes are ubiquitous, found in films, TV shows, commercials for different brands of cars, sneakers, perfumes, cosmetics, jeans, and in magazines. They considered that both DNA and genes have acquired symbolic meanings extending far beyond their biological meanings. These symbolic uses may still influence the viewer. McQuail (1979) considered that the process of learning through the media is ". . . a process which is often incidental, unplanned and unconscious for the receiver and almost always unintentional on the part of the sender" (p. 79). An advertiser using the iconic image of DNA to advertise a product such as a

car or a watch is unlikely to be intending to mislead viewers into believing that nonliving things contain DNA, but this may be an unintended result.

The Extent of the Influence of the Mass Media

It is evident that the mass media has considerable influence even though attempts at randomized samples and control groups have found it difficult to examine cause and effect. Livingstone (1996) suggested that the debate about the extent of the effect is "more about the epistemological limitations inherent in social science research than it is about the media in particular" (p. 308). She also contended that "the search for simple cause-effect links is inappropriate in media studies, for one should expect (rather than control for) diversity and variation in social phenomena" (Livingstone, 1996, p. 319). Van Evra (2004) cautions that it is beyond the scope of most studies to isolate completely the extent of the media influence on any one person or group of people, because the control of so many variables becomes impossible. Therefore, most work has a more epidemiological style, considering inferences, correlations and general trends rather than specific causal relationships and attempts to quantify the effect. This doctoral research is exploratory; its main aim is to search for "phenomena worthy of concern" (Anderson & Collins, 1988, p. 9).

Rideout, Foehr, and Roberts studied 2000-3000 US children aged 8-18 years at 5-yearly intervals, and their most recent 2010 data provide the best comparison for this doctoral research. Table 2.1 summarises media usage data and Table 2.2 summarises media impact data. These findings initially informed the specifics of the research design, for example, knowing that TV is still the dominant medium prompted the inclusion of more questions about TV shows, rather than other media, on the questionnaire. In Table 2.1, parts of the quoted statistics in the left column have page numbers for the source(s) listed in the right column. Table 2.2 consists of general paraphrased statements from the listed sources.

Table 2.1

Key findings in the literature concerning children's media usage

American Children (exact figures referenced)	Sources
Total media exposure now averages 10 hr 45 min/day but because they multitask 29% of the time, that equates to total media use of 7 hr 38 min per day (or 2737.5 hr/year) (p. 2)	Rideout et al. (2010)
TV the dominant medium (p. 2), average = 4.5 hr/day (p. 2), 20% of which is on mobile devices, "tweens" (aged 11-14) spend most time with media, an average of 12 hr packed into 8 hr 40 min/day, 5 hr of which is TV (p. 5)	Rideout et al. (2010)
High users of one medium are high users of others, except print (p. 12), most use more than one at once (p. 16)	Rideout et al. (2010)
Few differences between rural and urban children in how they use media (p. xxi), but affluence does have an effect: children who live in poor neighbourhoods spend more time with the media, especially watching TV	Van Evra (2004)
Radio, movies and comics displaced by TV viewing (p. 64); but not reading for pleasure or physical activity (p. 31), girls read more than boys and reading is the least multitasked media use (p. 31)	Anderson & Collins (1988); Rideout et al. (2010)
Computer use ≥ 1½ hr/day, mostly online (social networking, YouTube), 84% of homes have Internet (p. 20)	Rideout et al. (2010)
Rural children less likely to have a computer at home than urban children (p. 175)	Van Evra (2004)
Boys spend more time on computer as they do not tire of computer games as girls do as they get older (p. 22)	Rideout et al. (2010)
Boys play up to 2x as much E-games than girls on consoles, same amount on hand-held games, boys enjoy different types of games, have more games directed to them, E-game playing peaks from 11-14 yrs (pp. 25-26)	Rideout et al. (2010)

Table 2.2

Key findings in the literature concerning the impact of media

American Children	Sources
TV stimulates interest, may learn from entertainment TV, unknown whether it's fact/fiction to them	Anderson & Collins (1988)
Curvilinear association of TV viewing with academic achievement – improvement at low levels (up to 3 hr/day) especially with low socioeconomic status (SES) children, but lower achievement with high ($\geq$ 5 hr/day) of TV viewing, same effect on achievement in science. Heavy TV viewers more likely to self-report lower school grades.	Anderson & Collins (1988); CAP (1980); CAP (1988); Rideout et al. (2010)
Children more impacted by TV than adults (active development, absorb information from everywhere); serious viewing for information has maximum impact, viewing for diversion would have less impact.	Van Evra (2004)
TV is main source of information for, and has most influence on children: from disadvantaged homes; with reading problems; and those whose parents do not coview and provide extra information.	Van Evra (2004)
Coviewing with parents provides model of TV viewing behaviour; enhance understanding through comments; and provide background/alternative sources of information, particularly specialized scientific information.	Wright, St. Peters, & Huston (1990) Messaris (1986)
Coviewing with siblings less helpful than coviewing with parents: less information offered, and program choices made by older sibling, so younger children may be watching "older" programs than appropriate for them.	Wright et al. (1990) Wilson & Weiss (1993)
Impact of TV mediated by Amount of Invested Mental Effort (AIME), which varies with age, gender, type of TV show, and motivation for watching TV at the time.	Salomon (1981, 1983, 1984)
Children who watch a lot may remember less because they invest less effort.	Cullingford (1984)

Summary of Domain 1 – Mass Media Influence

The discussion in the previous section represented an analysis of the vast body of literature that exists about the mass media. Evidence that the mass media *does* have an influence; three theories about *how* that influence might occur; and *what* it influences (that is, knowledge) have been presented. Two tables presented the specific data available in the literature concerning students' media use and its potential impact.

Two major gaps in the literature were highlighted. The first (and most important for this doctoral research) is the paucity of research on the influence of the mass media on the specific academic knowledge of its audience. I found no research that investigated the presentation of any specific concepts (scientific or otherwise) in the mass media and how that might influence students' understandings. The research presented in this thesis begins to address this gap and raises questions for further research in this area. The second gap highlighted is the apparent lack of evidence that students can learn science from the media, despite the popularity of science-based media targeted at them. This research does not address this second gap.

The next section of this literature review examines the second domain of the development of students' understandings of genetics.

Aspect 3: Second Domain - Specific Concepts of Genetics

This section compares current approaches to genetics curricula with views from expert geneticists on key genetics concepts students require for scientific literacy. Also examined is what is known about how and when key genetics concepts form, common misconceptions that students have been found to hold, and how these misconceptions could be avoided or challenged.

Incidence of Key Genetics Concepts in Current Curricula

To start from what is currently taught, a survey of the teaching sequences from the curriculum frameworks and syllabuses available in the states and territories of Australia in 2010 was completed, and the full results, with details of the versions of documents consulted, is presented in Appendix A, Table A1. The survey showed that most genetics topics are covered in Years 9 or 10. The exception is an introduction to cells, which is included as early as Years 5-6 in Tasmania, and Years 7, 8 or 9 in the other states and territories. The new Australian Curriculum: Science (NCB, 2009, updated

online in December 2011 as ACARA v3.0, 2011) mentions cells and mitosis in Year 8, but with no mention of DNA, genes, chromosomes or other specific genetics concepts.

Surveying the curricula showed that most provide a one-time approach to the teaching and learning of genetics concepts, with little or no opportunity to establish core understandings, then elaborate and build upon them. Unless students opt for further biological studies in senior school, a "one-shot" unit is their sum exposure to genetics. In the most recent data available, only 25% of Year 12 students across Australia enrolled in biology in 2007 (Goodrum et al. 2011). Thus, for the majority of students, their future literacy in genetics relies on their compulsory exposure to genetics in Year 10.

In previous research, a number of genetics experts from various subdisciplines of genetics explicated possible contenders for key genetics concepts (Donovan & Venville, 2004; Venville & Donovan, 2005b, 2005d). These experts were specifically asked *not* to consider what students required in order to pursue genetics studies at the tertiary level, but to focus on their perceptions of genetics understandings needed for modern life. Although there were some differences – not surprisingly, the molecular geneticists favoured the molecular concepts about the nature of genes and DNA, whereas population geneticists were more interested in phenotype and the influence of the environment – there was some level of agreement on the key concepts. Table 2.3 elaborates the key concepts and compares them with current curriculum documents. The second column indicates which Australian states mention the key concepts in their current curricula. A single statement in the Australian Curriculum: Science (ACARA v3.0, 2011) indicates compulsory teaching of genetics in Year 10, namely, "The transmission of heritable characteristics from one generation to the next involves DNA and genes." Detailed statements are provided in the elaborations within the curriculum, shown in Table 2.3 in *italics*.

Table 2.3 indicates that there are several important omissions of key concepts in the Australian Curriculum: Science and state curricula. These include an understanding of alleles, polygenes, the expression of genes through the action of proteins, and the role of the environment in mediating the expression of genes.

Table 2.3

Key genetics concepts and their inclusion in Australian state curriculum documents

Key concepts in genetics as suggested by expert geneticists in Donovan & Venville, 2004; Venville & Donovan, 2005b, 2005d	Inclusion of these concepts in Australian state curriculum documents and the *Australian curriculum (ACv3.0)*
DNA – in cell nucleus, manages functions of cells through directing the proteins made.	New South Wales (NSW), Victoria (VIC), Tasmania (TAS), Western Australia (WA), *ACv3.0 no mention of nucleus, DNA is blueprint*
Genes – complex structure but essentially genes are sections of DNA with a particular role.	NSW, VIC, Queensland (QLD), TAS, WA, *ACv3.0 covers only the structural relationship of DNA, genes, chromosomes, not function*
Alleles – alternative forms of genes that produce different outcomes.	**NONE**
Chromosomes – tightly coiled duplicated DNA seen during cell division.	NSW, QLD, WA, *ACv3.0 mentions chromosomes but not with meiosis*
Use terminology correctly such as genes/alleles, chromosomes/chromatids, genotype/phenotype.	**NONE** (only WA extension ideas mention genotype/phenotype), *ACv3.0 mentions genotype/phenotype only*
Genes usually work together (i.e. realise that single gene yields 1trait as per Mendel is not the norm, more important than learning a lot about Mendel, monohybrid crosses and Punnet squares).	**NONE** deal with the issue of poly genes controlling traits (TAS, South Australia (SA), and WA mention monohybrid crosses, Punnet squares, and pedigrees) *ACv3.0 mentions simple ratios, crosses of gene pairs*
The role of proteins in doing the work of genes (considered more important than the details of transcription and translation).	NSW
That diversity in the genome results primarily from mutation.	NSW, VIC, TAS, and WA, *ACv3.0 mentions mutation as changes in DNA or chromosomes, factors that contribute to causing mutations*
The influence of the environment upon the ways genes act.	NSW
Ethical considerations discussed such as concepts of risk, making decisions about genetics, and genetic privacy issues.	NSW, TAS, SA, and WA (though not these issues, more on cloning and genetic modification of foods)

The first omission is that an understanding of alleles is essential to understand why the statement "genes cause disease" is incorrect. Genes direct appropriate biological functions; however, one form of a gene (one allele) may result in a gene product incapable of correctly directing this function, resulting in the development of a disease. Simplistic portrayals of genetics imply that there are only two possible alleles for each gene, but, for example, three alleles interact to produce the ABO blood groups, and hundreds of alleles (mutant forms of a gene that controls cell membrane function) can result in the development of the disease cystic fibrosis. However, each person inherits any two of the possible alleles that exist for a particular gene and the inherited combination establishes the outcome or phenotype.

As also seen in Table 2.3, the expert geneticists strongly expressed the importance of introducing the idea of polygenes (Donovan & Venville, 2004; Venville & Donovan, 2005b, 2005d) to move away from "one gene causes one trait" ideas that characterised early studies of genetics. For example, single genes do not determine human eye colour or skin colour; groups of genes control these traits. This polygenic nature gives rise to the continuous variation seen in humans, where eyes are not just brown or blue, but also many shades of hazel and green, and skins are many different shades of brown. These ideas are explainable in concert with the idea that genes act through directing the production of particular proteins. If these proteins are capable of acting as enzymes, they control biochemical pathways which lead to the presence (or absence or relative quantity) of cell constituents (such as particular pigments). Appreciating the actions of different alleles is only possible by first understanding that genes produce proteins. Wood (1993) called for the teaching of these concepts yet the Australian Curriculum: Science omits both polygenes and the role of proteins.

Table 2.3 indicates that students in New South Wales (NSW) currently receive the broadest compulsory genetics education, including the role of proteins and the influence of the environment upon genes. I hope that teachers in NSW will continue to rely on what they have been used to teaching, as the Australian Curriculum: Science (ACARA v3.0, 2011) omits both of these key ideas. The idea that genes act within an environment, both internal and external, explains why some people carrying a particular allele as part of their genotype will express it in their phenotype whereas others who also have that allele, do not. In our prior research (Donovan & Venville, 2004; Venville & Donovan, 2005b, 2005d), one expert geneticist suggested using the example that humans (unlike most other mammals) lack the gene that enables the

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synthesis of vitamin C. This genotype predisposes all of us to develop vitamin C deficiency disease (scurvy) and yet most of us do not as we obtain sufficient vitamin C from our diets (our usual environment). Yet in certain extreme environments, such as a long sea voyage where fruit and vegetables are not available, scurvy develops.

Particularly interesting are the terms "dominant" and "recessive," not specifically mentioned by the experts we interviewed. These terms are widespread in textbooks, in medical genetics literature written for the public, and on the Internet, but there are calls to abandon these terms. For example, Allchin (2002) explained how subscribing to the idea of dominance being a rule necessitated the production of a suite of terms such as incomplete dominance, codominance, and penetrance to explain the exceptions to the rule. Further, Allchin (2002, p. 51) pointed out that the vernacular meaning of dominance, where one thing overpowers another, has given rise to misconceptions such as dominant traits are stronger, better, more prevalent in the population, and more "fit" in terms of natural selection. More recently, Germain (2006) and Dobyns (2006) suggested in the medical literature to abandon the terms dominant and recessive for X-linked diseases, because females who should not show the disease according to the rule of dominance, do exhibit intermediary forms of the disease.

Can we do without terms such as dominance when teaching and learning genetics in schools? It is possible, but only when the actions of alleles are explained biochemically. For example, in blood groups, the "A" allele causes the expression of glycoprotein A on the red blood cells, the "B" allele causes the expression of glycoprotein B on the red blood cells, whereas the "O" allele does not cause the expression of either glycoprotein A or B on the red blood cells. People who have an "A" allele and a "B" allele have both glycoproteins A and B on their red blood cells (and are termed blood group AB). People who have two "O" alleles are termed group O – standing for "none" (neither A nor B glycoproteins). People who have an "A" allele and an "O" allele only express glycoprotein A on their red blood cells and so are termed group A. To do without dominance, it becomes essential that the concepts of alleles and expression of protein/polypeptides are made clear, in that for each trait, the expression of each allele must be understood in order to comprehend how they work together to establish a joint phenotype. The Australian Curriculum: Science (ACARA v3.0, 2011) retains the idea of dominant/recessive in the absence of alleles and their actions through proteins.

In our prior research (Donovan & Venville, 2004; Venville & Donovan, 2005b, 2005d), the expert geneticists suggested ways to teach the key concepts effectively. Suggestions included introducing biological vocabulary early on to develop literacy and pointing out that if young students can use dinosaur names, then the words cells, DNA, genes, chromosomes, and proteins should not prove too difficult. The experts felt that children should learn basic definitions of these words in primary school to enable them to learn the complexity such as exons and introns in genes later on. They suggested using more models, pictorials, and spatial approaches to demonstrate the relationships between the key structures. These twin ideas of introducing vocabulary early and using models led to the development of a wool model successfully used to introduce the essential vocabulary of DNA, gene, allele, and chromosome at a variety of age levels (Donovan & Venville, 2005a, 2006; Venville & Donovan, 2006b, 2007, 2008). Finally, the expert geneticists also suggested using evolution as a unifying concept linking genetics and environmental influence, and using bioethical issues to develop students' "need to know" more factual information about genetics (Donovan & Venville, 2004; Venville & Donovan, 2005b, 2005d).

How and When Students Might Develop Key Concepts

Venville and Treagust (1998) proposed a four-stage process for the construction of specific concepts about genes. These four stages were:

1. Genes as passive particles correlated with traits.
2. Genes as active particles that determine traits.
3. Genes as instructions.
4. Genes as productive instructions for proteins.

Lewis and Kattman (2004) found that many of their participants were stuck in Stage 1 (those fixated on genes as unchanging particles passed on from one generation to the next), some were in Stage 2 (with deterministic views of genes), and some were in Stage 3 (who confused gene with genetic information). Few, if any, made it to Stage 4. Appendix A, Table A2, presents details of known misconceptions from worldwide research. Viewing the commonality across age groups in the misconceptions as presented in Appendix A, Table A2, further indicates that this four-stage trajectory is an accurate reflection of the process.

Considering why students "get stuck" and find genetics so difficult, a summary of the issues raised in the research base yields five identified problems:

1. 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).
2. Processes and entities in genetic phenomena are invisible and experientially inaccessible to students (Marbach-Ad & Stavy, 2000).
3. Explaining genetic phenomena entails reasoning across levels of organisation from cell to whole organism (Knippels, 2002; Duncan & Reiser, 2007).
4. Inappropriate treatment of concepts in high school textbooks (AAAS, 2005) in which too much attention to detail occludes the "big picture."
5. 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 (NRC, 2005).

These problems resonate with a Piagetian viewpoint, and provide reasons for delaying formal genetics tuition until Years 9 or 10. I do not deny these difficulties, but would point out that other intangible phenomena are taught at earlier ages. The Australian curriculum (both NCB, 2009 and ACARA v3.0, 2011) 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. 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 & Donovan 2006b, 2007, 2008).

In 1960, Bruner boldly suggested that no content should be off limits for school-age children. He said

> We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development. It is a bold hypothesis and an essential one in thinking about the nature of the curriculum. No evidence exists to contradict it; considerable evidence is being amassed that supports it. (p. 33)

Bruner went on to suggest that children are able to get an intuitive grasp of a complex concept before they have the background and maturity to deal with the same topic in a formal manner. More recently, Lehrer and Schauble's (2000) research showed that

revisiting science ideas enables students to understand and apply concepts that they would not typically understand until several years later.

Is there any evidence that young students can deal specifically with the complexities of genetics? Dairianathan and Subramaniam (2011) chose to test Grade 5 Singaporean students before, immediately after, and finally eight weeks after an intervention held at an out-of-school science centre. The intervention comprised a two-hour session called "DNA Detectives," run for 30-39 students at a time. This session capitalised on students' "fascination for crime stories, in part fuelled by popular television serials such as *CSI*" (p. 1084), to introduce them to concepts of cells, nucleus, DNA in living things, the relationship between DNA, genes, and chromosomes, the relationship between familial similarity and individual uniqueness, DNA profiles, and evidence for solving crime. This extensive list of concepts was addressed through targeted instruction involving videos, animations and a PowerPoint presentation, and practical activities involving micro pipetting, gel electrophoresis and other forensic techniques to interpret data from a murder, a robbery, and a paternity suit. Content covered was new to the students and mostly new to their classroom teachers as well. Due to time of year (before examinations), there was no follow up to the activity in schools.

That so much was covered in just two hours is amazing; the tests, particularly the delayed post tests eight weeks later, revealed significant and robust gains in student understanding of genetics in the experimental groups (with the intervention). Comparison of pretests between the experimental and control groups (without the intervention), showed that the groups were similar, there was no pretest effect, and all gains were therefore due to the intervention. Dairianathan and Subramaniam (2011) found that the Grade 5 students understood the content and could answer questions requiring application of that knowledge. Student enjoyment, desire to attend another programme on the same topic, self-perception of understanding DNA, and capacity to relate DNA to daily life were all rated highly by over 90% of the students. Only one out of 245 students in the experimental group found the content too hard to understand and another said they did not like the programme.

Despite this exciting research, concerns about and difficulties with teaching and learning genetics are not to be underestimated. It is indeed difficult to grasp ideas at an unseen molecular level and relate them through all the levels of tissues, organs, and systems up to the whole body. Yet few researchers are forward thinking towards

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generating alternative ideas and strategies for overcoming these difficulties. Most are still entrenched in the "one-time when they are ready for all the abstract concepts" approach, yet their own research shows that even at 14 years old, students are not coping with such intensive programs. It is possible that, when students reach this point, without a skilful intervention such as that studied by Dairianathan and Subramaniam (2011), students are overwhelmed with too much new vocabulary and too many concepts at once. Students may need more time to reflect, absorb, and make sense of newly presented genetics concepts.

An alternative approach could be a learning progression that begins genetics in primary school and continues with regular exposure through to Year 10. This could facilitate them through Stages 1 and 2 at an earlier age, giving the high school teacher optimal opportunity to scaffold their learning through Stages 3 and 4. Repeated exposure would give more opportunity for

- Students to reflect on how their ideas mesh with scientific ideas, i.e. personal constructivism.
- Social learning opportunities and scientific discourse with other students and their teachers, i.e. social constructivism.
- Situating the ideas in a real world context and for students to move from the periphery of the learning community to the centre as they become more expert.
- Examining the ideas that they are absorbing from the mass media, to ameliorate the confusion this may cause and instead play to its strength of making something that cannot be seen more tangible with rich visuals.
- An inquiry approach so students grapple with ideas themselves and move through the four stages of conceptual change in the learning of genetics.

Learning progressions need to be based on sound research that indicates what students at different ages are capable of learning. Duncan et al. (2009) commented

> While there exists a large body of research about students' understandings about genetics it still contains numerous gaps and is thus insufficient to develop a highly specific learning progression. In many cases the research base provides details about what students struggle with, but not necessarily what students are capable of doing with proper instruction. (p. 664)

This observation reflects the tendency of the research to tell, "What they can't do instead of what they can." Researchers tend to expend the bulk of their energy on pointing out why genetics is hard, what genetics understandings students fail to grasp, and in critiquing existing teaching methods (e.g. Banet & Ayuso, 2000; Duncan & Reiser, 2007; Knippels, 2002; Marbach-Ad & Stavy, 2000; Stewart & Rudolph, 2001).

Research by Kargbo, Hobbs, and Erikson (1980), Smith and Williams (2007), Springer and Keil (1989), and Venville, Gribble, and Donovan (2005) has shown that Year 5 students have experienced genetic phenomena; developed ideas about family resemblance as a foundation for ideas about offspring inheriting characteristics from parents via DNA or genes; and are interested in and receptive to such information. Consequently, Year 5 is a potentially suitable time to begin genetics instruction (Donovan & Venville, 2006). As most research has targeted high school students, achievable understandings for this age group are uncertain. Duncan et al. (2009) pointed out that, "interventions designed for the middle or late elementary grades are rare" (p. 658), citing only Venville and Donovan (2006a, 2007).

In particular, work with Year 2 (7-year-old) students (Donovan & Venville 2005a; Venville & Donovan, 2007, 2008) showed that these very young students were capable of using an analogical model to help them understand something they could not see. These 18 participating students faced extra difficulty in that they were from many different cultures, all spoke English as a second language, and all were identified in Year 1 as requiring remedial assistance. This is why they were in a relatively small class in Year 2. However, the classroom teacher was completely confident that her students knew what *pretend* meant and would understand that the wool model I had designed was a *pretend* or *imaginary* way of looking at genes and DNA. When I first approached her regarding her students' learning about DNA, genes, alleles and chromosomes, I asked if she thought this would be too difficult. Her reply was that, "If my students can volunteer words like *Tyrannosaurus rex* and *Brontosaurus*, how hard can it be to learn DNA, genes and chromosomes?" In this, she unknowingly echoed the words of the experts consulted earlier (Donovan & Venville, 2004).

In post test conditions, two weeks after exposure to these ideas and with no further consolidation, the participating Year 2 students demonstrated clear understanding that genes are made of DNA; that these molecules are responsible for our appearance being similar to our parents; and that identical twins would have the same DNA as each other. The model enabled them to learn some valuable genetics vocabulary and to link it with

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concepts of family identity (Donovan & Venville, 2005b; Venville & Donovan, 2007, 2008). The same three papers also reported on similar results with Year 5 students. Consistent with Carey (2010), I do not claim that this fast mapping of the words genes and DNA enabled students to develop full understanding of the words with all nuances of meaning. However, the point is, that in the current nonspiral curricula, which do not afford further exposure and opportunities for discussion and instruction, the extended mapping of these concepts which Carey (2010) describes so clearly in the context of her research, will not occur. Opportunity has been lost.

Based on the research I conducted with the Year 2 students (Donovan & Venville, 2005a; Venville & Donovan, 2008), I concur with Willingham's (2008, p. 39) notion that, "Without trivializing them, complex ideas can be introduced by making them concrete and through reference to children's experience." The ideas were made concrete by using a simple model made of wool. By each child getting individual models to represent their own DNA (and the identical twins in the Year 2 class getting the same), the complex idea was referred to their experience (Donovan & Venville, 2005a; Venville & Donovan, 2008).

Despite their reservations concerning the lack of research about younger students, in 2009, Duncan et al. produced a learning progression that introduces initial genetics concepts in Year 5 and continues to develop them each year into Year 10. Duncan et al.'s (2009) learning progression took Stewart, Cartier and Passmore's (2005) ideas about model-based inquiry, unpacked the big ideas further, and expanded it to include the environment as the milieu for genetic expression. Inspection shows the learning progression to have a sound basis in research, and feasible to teach at the levels proposed. Another research group (Roseman, Caldwell, Gogos, & Kurth, 2006) produced a different learning progression that introduces proteins before DNA, and in turn, discusses DNA before moving on to genes and chromosomes. Their rationale is that it will be more developmentally appropriate to introduce concrete physical entities such as proteins and DNA before the more abstract notions of genes and alleles. This has some appeal because it parallels the historical discovery whereby proteins preceded nucleic acids. However, as elucidated in the discussion of common misconceptions in the next section, one important difficulty students have is in relating DNA, genes, alleles, and chromosomes to each other, so it may be more appropriate to use these relationships as a starting point in both learning progressions.

Unfortunately, as presented in Table 2.3, the new Australian Curriculum appears to have ignored this body of research, clinging to the one-time approach for all the genetics concepts in Year 10, later than in some state curricula. There is very little evidence of any spiralling of the curriculum in any of the science strands, and it has been criticised for lacking this (Haeusler, in press). Haeusler also noted that cells, genetics, and conservation of energy are important "big ideas" in science that are essentially missing from the curriculum. Haeusler further suggested that lack of articulation between specific topics and big ideas might lead to fragmentary topic-based teaching, rather than constructive development of the big ideas.

What Misconceptions are Known to Exist?

There appears to be scant scientifically accurate understanding held by students worldwide about the structure and function of DNA, genes, and the process of inheritance. This may well be expected in students not yet exposed to teaching of genetics in school, yet researchers in the UK (Lewis & Kattman, 2004) and in the USA (Lestz, 2008; Mills Shaw, Van Horne, Zhang, & Boughman, 2008) found the situation little different in students who had been taught genetics. For this situation to improve, researchers are united in the idea that teachers need to know more about the nature and origins of the misconceptions, as well as appropriate strategies for working from these erroneous ideas towards more scientific ones.

In Appendix A, Table A2 gives the full details of 24 known misconceptions, the specific research that uncovered each misconception, and the correct scientific conception. These 24 misconceptions from the collective research of Berthelsen (1999); Chattopadhyay and Mahajan (2004); Donovan and Venville (2004); Duncan and Reiser (2007); Engel Clough and Wood-Robinson (1985); Lestz (2008); Lewis and Kattman (2004); Lewis and Wood-Robinson (2000); Marbach-Ad and Stavy (2000); Mills Shaw et al. (2008); Venville and Donovan (2005a); Venville, Gribble, and Donovan (2005, 2006); Venville and Treagust (1998); and Wood (1993) are simply listed here.

List of known misconceptions many students hold about genes and DNA.
1. That genes and DNA are two completely different things.
2. That genes make you resemble your family, whereas DNA is what makes you unique and identifiable, primarily as a prime suspect.
3. That DNA does not have a biological function; it is just there to be shed at crime scenes.

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4. That DNA is only found on the outside of the body (skin, hair, and fingerprints) and in the blood (possibly only in the left arm!).

5. That DNA can be found in some nonliving things (e.g. cars) but might not be in some living things such as plants, fungi and microorganisms.

6. That genes are the characteristics or traits themselves.

7. That a gene makes a specific body part (e.g. hands), also seen in the belief that humans inherit a gene for *tall* just as Mendel's pea plants did.

8. That particular genes are found only where they are expressed (so nerve cells would contain different genes from cheek cells).

9. That single genes exist "for" particular traits (e.g. for fat legs, or chemical dependency) i.e. the student holds deterministic beliefs.

10. That heredity is the transfer of discrete, unchanging trait-bearing particles.

11. That a trait that appears in one generation must have existed in at least one of the forerunning generations, they are "hidden" traits.

12. Ascribe vague or inappropriate biological functions to genes (such as controlling blood sugar), which occur by unknown mechanisms.

13. Cannot distinguish between gene and genetic information.

14. Cannot distinguish between genotype and phenotype.

15. Cannot associate genes with proteins or explain gene products.

16. That genes exist only to cause disease, especially in babies, i.e. holds deterministic beliefs.

17. That all chromosomes are either X or Y.

18. That girls get more DNA (or genes, chromosomes, genetic information) from their mothers and boys get more from their fathers.

19. That genetic information (or chromosomes) are not copied before being shared out, or cannot explain conditions resulting from abnormal chromosome numbers. They may think that offspring have a complete extra set of chromosomes.

20. That information from mothers and fathers may be differentially expressed (e.g. if you look like your Mum on the outside, your organs on the inside must run like Dad's).

21. Cannot represent accurately the chances of inheriting alleles in dominant and recessive traits (e.g. stating that if neither parent has or carries a recessive gene, there is a 25% chance of a child having the trait).

22. That the term hereditary is equivalent to a trait having a genetic component.

23. That eugenics (the practice of "improving" the human race by deliberate design) is the main goal of genetic research.

24. That a single genetic discovery will provide a cure for most diseases.

The different studies asked different questions of different age groups, so this is a compilation of all the misconceptions found. A comparison of this misconceptions list with the list of key concepts generated by expert geneticists as presented in Table 2.3 reveals that the suggestions from the experts were remarkably appropriate. A well-designed program to introduce and establish their key concepts would potentially address all 24 misconceptions. The misconceptions list also lends considerable support to the earlier discussion concerning the inadequacy of the current curricula in terms of addressing these key concepts. The areas missing in the curricula are essential background content knowledge to challenge some of these identified misconceptions. It is unlikely that the misconceptions list will diminish in the future unless curriculum developers take notice of the prevailing research into the teaching and learning of genetics. Finally, it is also remarkable that the suggestions for teaching the key concepts as offered by the expert geneticists (presented earlier), are so similar to the learning progressions devised later by expert educators such as Duncan et al. (2009).

Lewis and Kattman (2004) pointed out that students holding Misconceptions 1, 9 and 10, are set up to further develop Misconceptions 8, 12, 13, 14 and 15. 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.

Ridley (1999) suggested that the ideas of Misconception 16 arise from ignorance, rather than knowledge, pointing out that all we know of some genes is what happens when they malfunction. His extensive argument centres on that idea that to say there is a gene "for" a disease is as absurd as saying livers exist to cause cirrhosis, it is a sloppy figure of speech rather than a reflection of reality. Mills Shaw et al. (2008) attributed Misconception 16 to a combination of factors. Firstly, to media hype, and secondly, to the inappropriate use of language by scientists in the media (e.g. they should refer to the mutation in the cystic fibrosis gene that leads to the disease, instead of calling it the "cystic fibrosis gene"). Thirdly, to standards for high school education concentrating on monohybrid crosses and Punnet Squares instead of requiring students to learn about polygenic inheritance. Mills Shaw et al. (2008) also attributed Misconception 23

regarding designer human babies as possibly resulting from teachers using this idea to engage the students, or from exposure to the media.

Why are these misconceptions important?

Chattopadhyay and Mahajan (2004) recognised that rapid advances in genetics raised ethical, legal, and social issues, particularly in the field of genetic technologies, and that a scientifically literate population was needed for informed decision-making. In the same vein, Duncan et al. (2009) commented

> The challenge of helping students become scientifically literate is particularly acute for domains in which scientific advances are rapid, phenomena are complex, and the amount of accumulated knowledge is daunting. Modern genetics presents a compelling example of such a domain. . . . Citizens are expected to be able to make decisions about genetic screening, stem cell research, genetically manipulated foods, etc. Without a sound understanding of core ideas in genetics – such decisions are, at best, uninformed. (p. 655)

These authors strongly assert that to be effective future citizens, today's students need to have strong foundational knowledge about genetics, particularly genes and DNA. The foregoing list of some 24 common misconceptions shows how far off that prospect currently is. Trying to find out more about what influences students' understandings so we can approach this ideal of an informed citizenry is one of the key drivers behind this research.

How can misconceptions be reconstructed?

Researchers have varying ideas about how to improve students' genetics knowledge, and achieve conceptual change. All rely on both teachers and students understanding student misconceptions in order to work from everyday models towards more scientifically accurate understandings. Lewis and Kattman (2004) proposed beginning with activities that demonstrate that gene and trait are not equivalent and that genotype and phenotype act at different levels of bodily organisation. They considered students will then be more receptive to learning about the mechanism of gene action and gene switches rather than the everyday logical but nonscientific notion that different cells must contain different genes.

Stewart, Cartier, and Passmore (2005) proposed firstly working with models in general with students so that they learn to appreciate these as conceptual constructs

rather than miniature replicas. These researchers then devised a detailed program of inquiry-based activities leading students to devising their own explanatory models for various genetic phenomena. This discovery-learning program is exciting, but time-consuming, and requires teachers to be skilled facilitators of this approach.

diSessa (2002) noted that conceptual change involves not merely replacing false ideas with correct ones in a one-to-one manner, but of changing the organisation of knowledge networks by introducing new ideas and restructuring connections between existing ones. Therefore, to change a student's misconception that the sole use of DNA is for solving crime, the first step is to expand their knowledge network about DNA, that is, its location and function in cells. The second step is to connect this information to existing ideas about DNA being found at crime scenes (due to its presence in cells) and being able to identify suspects (due to it being specific to each individual). This parallels the ideas of Lewis and Kattman (2004) who proposed that it is not so much a matter of abandoning preconceptions and replacing them with scientific ideas, but "rather an evolutionary process of assimilation and conceptual capture in which previous conceptions are reconciled with new conceptions" (p. 204).

Previous research (Donovan & Venville, 2005a, 2005b; Venville & Donovan, 2006a, 2007, 2008) clearly demonstrated that reconstruction of ideas about genetics is possible across a range of ages with appropriate challenge activities. In particular, the wool model that tangibly demonstrates the physical (structural) relationships between DNA, gene, allele, and chromosome was particularly helpful. The use of the model established initial understandings in Year 2 students (Donovan & Venville, 2005a), yet Year 12 students found it helped them clarify their more sophisticated understandings achieved from extended genetics tuition (Venville & Donovan, 2008). Used with younger students, the wool model also demonstrated its potential for the next type of strategy, avoidance of the development of misconceptions.

How can misconceptions be avoided?

As discussed, Duncan et al. (2009) and Roseman et al. (2006) have proposed different learning progressions to begin developing genetics ideas in students at a younger age, and therefore, over more time. These approaches aim to introduce concepts in a scientific way before students acquire nonscientific concepts. These researchers also regard conceptual change as something that requires time, and careful scaffolding of activities by the teacher to enable students to construct networks of scientific understandings.

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Student misconceptions may arise from those held by teachers. In a competition that asked teachers to send in genetics essays from their top three students, Mills Shaw et al. (2008) noted that 55.6% of the essays reviewed exhibited a major misconception. They expressed concern that the student writing might be indicative of misconceptions held and perpetuated by teachers, with serious implications for instructors of undergraduate biology for preservice teachers in USA. Cardak and Dikmenli's (2008) work with preservice science teachers in Turkey implies that Mills Shaw et al.'s (2008) concerns are probably entirely founded unless the standard of undergraduate biology education for teachers is completely different in the two countries. Thus, challenging teacher misconceptions will also require effort.

Mills Shaw et al. (2008) also encouraged scientists to spend time in classrooms with students and teachers and urged them to be extra careful with their use of language when communicating to peers, press, and the community. Reviewing the standards documents guiding teaching and learning programs in the USA, they suggested a need for greater uniformity in their requirements, and more specific guidance for teachers. They queried the concentration on Mendel's work given its limited explanatory power for human genetics and called for changes to curricula and methods, in the hope this would reduce the incidence of misconceptions in future. The concerns expressed by Mills Shaw et al. (2008) reflect my position with respect to Australian curricula, particularly the Australian Curriculum: Science (ACARA v3.0, 2011).

The research presented in this section has suggested ways of facilitating conceptual change and reconstruction of ideas, as well as ways to avoid the establishment of these misconceptions. Suggestions included different teaching and learning programs, some of which involve starting formal genetics tuition at an earlier age than is currently usual. Knowing more about how and when these misconceptions arise will inform both reconstruction and avoidance strategies. The research presented in this thesis will shed light on whether (and when) the mass media might be a source of some of the misconceptions held by students. With this knowledge, teachers would be more able to challenge these ideas with carefully designed classroom activities involving critical thinking exercises. This could lead to their students developing stronger literacy skills for interacting with science in the media.

Summary of Domain 2 – Specific Genetics Concepts

The discussion of this domain included the genetics concepts that expert geneticists believe students require, and 24 common misconceptions held by students. The research base into the conceptual processes of learning genetics shows that current teaching and learning approaches are not working. Learning progressions in which formal instruction in genetics begins at Year 5 are potentially more effective strategies. Implementation of learning progressions may also provide students with a scientific foundation about these topics before or at the same time as students absorb these ideas from the mass media.

Aspect 4: Drawing the Literature Together

This chapter concludes by focusing on possible links between the two domains of the mass media and specific concepts about genetics.

In Students

Prior to this doctoral research, there was no direct evidence of links between the mass media and genetics concepts expressed by students, just inference. I found no literature that focused explicitly on such links in terms of students of primary/middle school age. In my previous research, (Venville & Donovan 2005a, 2005c; Venville, Gribble, & Donovan, 2005), I did not probe the sources of information of the students interviewed. However, some interviewees mentioned specific sources such as the popular forensics TV show *CSI* when expounding their ideas that DNA is purely for forensic scientists to discover so they can identify someone as the prime suspect. Expert geneticists also suggested that student misconceptions might result from exposure to the mass media (Donovan & Venville, 2005a; Venville & Donovan, 2005b, 2005d). These ideas provided an initial stimulus for this doctoral research.

Some studies mentioned links between the mass media and students' understandings as an inference rather than a researched phenomenon. For example, Mills Shaw et al. (2008) 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 went on to mention that, "A cursory search of online news outlets yielded example headlines that could easily be misinterpreted, adding credibility to students' misconceptions" (Mills Shaw et al. 2008, p. 1165), and gave an example, "Turning off suspect gene makes mice smarter" (*New York Times*, May 29, 2007). Duncan et al. (2009, p. 657) also mentioned several *New York Times* headlines, such as "Scientists discover gene linked to higher rates of prostate cancer" (May 8, 2006), 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.

A similar cursory search in Australia yielded similarly inappropriate representations of the concepts of DNA and genes. In that search, almost every newspaper article that mentioned DNA linked it to crime, or, more confusingly, to inanimate objects such as cars. Other common links were between genes and disease; specifically links of genes with babies with diseases in very deterministic language. This preliminary evidence suggested that this doctoral research to attempt to fill this gap in the literature was warranted.

In Adults

Understanding of science by the public is becoming a more active field of research. As part of their dismay at the results of the genetics essay competition, Mills Shaw et al. (2008) commented that scientists must work proactively with professional science writers to make sure that the press accurately represents their information. A scientist raised this issue to me at a conference, "But scientists don't write the articles, writers do. How do we know it's not their fault?"

Yet when D. Ransohoff and R. Ransohoff (2001) compared the text of original science articles with news reports about them, they reported that when they identified "hype" in the popular press, it was the result of the original article and the scientists' own interpretations of their results. They called scientists and journalists "complicit collaborators" as both stood to gain from a sensational story. Due to the tremendous funding pressures that scientists work under, they need to make the results sound as spectacular as possible in order to attract more funds for further research, and, the bigger the story, the more status for the journalist.

Bubela and Caulfield (2004) stated that, "The public gets most of its information about genetics from television, radio, magazines and newspapers" (p. 1400), and yet "Surprisingly few systematic studies have examined the accuracy of media reporting in

the context of genetics, most focusing on coverage of a single issue, such as sexual orientation or the discovery of susceptibility to breast and prostate cancer" (p. 1400). Their comparison of print media stories from respected newspapers with the original scientific articles about genetics, found exaggeration in 37% of news stories, with 11% being highly exaggerated. They found evidence that the media was framing which aspects of genetics the public read about: a more subtle form of hype. Stories about behavioural genetics and neurogenetics were overrepresented compared with their representation in the scholarly literature.

Condit (1997) found that the media tend to take shortcuts, using shorthand phrases and terms such as "the breast cancer gene," possibly leading to public misunderstanding. A recent study by Brechman, Lee, and Cappella (2009) found

> . . . genetic discoveries are presented in a biologically deterministic and
> simplified manner 67.5% of the time. The introduction of deterministic
> language is attributed equally to both press releases and news coverage.
> Also, there are substantive differences between content introduced in the
> press release and content presented in subsequent press coverage; in fact,
> when two sources report on the same scientific discovery, the information
> is inconsistent more than 40% of the time. (Abstract)

Brechman et al. (2009) also found deterministic language in both print and nonprint media plus significant inconsistencies. Reviewing these studies begs the question as to whether the quality of reporting about genetics is deteriorating over time.

Weiner, Silk, and Parrott (2003) found that media exposure relates to families' discussions about human genetics research. Based on nine questions that families answered about their media exposure, they found talk shows, newspapers, movies and television medical dramas were the sequence of sources from most to least that correlated with the propensity of families to talk about genetic testing, although in general, families seldom discuss genetic issues at all. The responses of adults form the basis of these findings; it is probable that students would have less exposure to talk shows and more to medical dramas.

Based on this research, a reasonable hypothesis is that television is more likely to influence young students than is print media. Further, the likelihood of young students reading news stories in "respected" newspapers is fairly low, so they may be exposed to more sensationalism and hype about genes and DNA than this review would imply.

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Chapter Summary

The breadth of the research topic required the examination of two domains of literature in a background context of knowledge and learning theory. In doing so, the following three aims have been achieved.

Firstly, the fields of learning theory and conceptual change theory have been examined, particularly the rationale for the choice to term students' nonscientific ideas of genetics as misconceptions, rather than using alternative terminology. This created a platform for understanding how students acquire ideas and process them to become knowledge.

Secondly, this chapter presented evidence that the mass media *does* influence the knowledge of people and three theories concerning how such influence may occur. There is a lack of research into how the mass media may influence knowledge acquisition of students particularly in terms of science, and none into the influence of entertainment media on students' academically relevant knowledge, that is the focus of this research. However, considering this domain within the background context, it would appear that there is a genuine possibility that students will have acquired knowledge from their exposure to the mass media.

Thirdly, a description of the situation as it prevails in the teaching and learning of genetics involved presenting the concepts that experts agree are important, and the 24 common misconceptions held by students. Weaknesses in the research to date into the teaching and learning of genetics were highlighted and potential resolutions to the problem suggested.

I acknowledge that this discussion is not an exhaustive treatment of the vast literature that pertains to these two domains. This was not my intent; rather the aim was to draw upon the literature in a balanced manner to create a cogent conceptual framework pertinent to the design and interpretation of this doctoral research. This framework points to the plausibility of the mass media having influence on the genetics understandings of young students.

This doctoral research was the first to look for the existence of a nexus between the mass media and student learning with respect to specific understandings of genetics. With the lack of prior research, this study was necessarily exploratory; in the words of Anderson and Collins (1988), it was not seeking to elucidate cause and effect; but whether there are "phenomena worthy of concern" (p. 9). The search was not for

definitive answers, but for better questions, from which to derive testable hypotheses for future research. Other specific data collected, such as primary students' viewing of crime shows and what they perceive to be their main sources of information about genetics, are also new, and add to the literature regarding students' interactions with the mass media.

The next chapter, Chapter 3, develops the exploratory design of this research. It includes the rationale for the methodology and describes in detail the methods used to collect and analyse the data. Chapters 4 and 5 present the data and the findings of the analysis.

Chapter 3 – Methodology

Introduction

This chapter presents the methodology for this research. The chapter begins with the rationale for the selection of the mode and general design of the research. Then follows the particulars of the design, including the participants and tools selected for the research, the process of data collection, the types of data obtained (quantitative and qualitative), and the methods of analysis used to answer each research question. The final section addresses issues of trustworthiness and the ethics of the research process.

Rationale for the Mode and General Design of the Research

As outlined in the literature review in Chapter 2, this doctoral research incorporated three different dualities. Firstly, it involved both the social sciences (mass media) and the sciences (genetics). Secondly, it incorporated two distinct paradigms, scientific and educational. Thirdly, one aim of the research was to "… both generalise the findings to a population as well as develop a detailed view of the meaning of a phenomenon or concept for individuals" (Creswell, 2009, p. 18). Trochim (2006) describes such research as both nomothetic (seeking laws and generalisations) and idiographic (seeking to describe an individual situation).

The literature review also revealed that no prior research specifically probed possible relationships between exposure to the mass media and student conceptions about genetics, nor any other scientific conception. Consequently, it was not appropriate to construct either an experimental or quasi-experimental research design seeking causal relationships (Trochim, 2006), as there was inadequate existing information available to guide the identification of specific variables and to generate a fair test. It was necessary to answer an "are there any signs of influence?" question before addressing "what does it influence?" Therefore, a nonexperimental research design explored a possible correlative relationship between the two variables of mass media influence and student conceptions of genetics, with a view to providing the necessary background information to facilitate future research on causal relationships.

"Social research, in simplest terms, involves a dialogue between ideas and evidence. Ideas help social researchers make sense of evidence, and researchers use evidence to extend, revise, and test ideas" (Ragin, 1994, p. 55). Due to the lack of prior research in the area of interest, this doctoral research began with broad ideas about

possible influences of the mass media on students' understandings of genetics. These ideas arose, as many do, from "everyday life" (Ragin, 1994, p. 59), specifically, conversations about the results of prior research.

However, these ideas were not set in one analytic frame of "negative influence." Although my first thought was that "Students who are more exposed to the mass media are likely to have more misconceptions about genetics," I recognised that the media could also have a positive influence, increasing students' knowledge about genetics. Being open-minded about the initial ideas and the subsequent evidence constitutes the "possibility of surprise" that is Rule Number 1 in Firebaugh's (2008) *Seven Rules for Social Research.*

This study therefore required the accumulation of evidence that might fit either positive or negative analytic frames, evidence that would enable the extension, revision, and testing of these initial ideas. With no existing evidence, the goal of this research was inevitably exploration rather than description or explanation (Ragin, 1994), and exploration as a process requires both analysis and synthesis of data. Achieving this goal necessitated a flexible research design including the collection of wide-ranging evidence rather than intensive evidence based on one situation.

"Research design … involves the intersection of philosophy, strategies of inquiry, and specific methods" (Creswell, 2009, p. 5). This research was underpinned by a "post-positive critical realist philosophy" (Trochim, 2006, Positivism and Post-positivism, para. 6) that supports the notion that there is a reality for science to study, but that all observation is fallible and theory is revisable. Creswell's writing on the philosophy of research (2009) suggests four worldviews that afford different orientations about the world and the nature of research. He points out that, "These worldviews are shaped by the discipline area of the student, the beliefs of advisers and faculty in a student's area, and past research experiences" (Creswell, 2009, p. 6). My discipline is science; my adviser is a science educator, and my past research experiences are in both science and education. This background, along with the nature of the topic, provoked strong alignment with the pragmatic worldview.

With regard to pragmatism, Creswell (2009, pp. 10-11) states that

- Pragmatism is not committed to any one system of philosophy and reality.
- Researchers are free to choose the methods, techniques, and procedures of research that best meet their needs and purposes.

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- Investigators use both quantitative and qualitative data because they work to provide the best understanding of a research problem.
- Thus for the mixed methods researcher, pragmatism opens the door to multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis.

The combination of all of the above aims and considerations led to the conclusion that a mixed methods mode as described in Creswell (2009) was the optimum strategy of inquiry for this study. It is an accepted form of research in both disciplines and suits both paradigms. This strategy facilitates the collection of wide-ranging and different types of evidence that suit the exploratory nature of the study. Examining the data at both group and individual levels yields both big and small pictures. The capacity to interrogate different types of data enables both analysis and synthesis. The mixed methods mode is appropriate for a pragmatic worldview, which suited both the nature of the research and the researcher. Finally, a mixed methods mode involves the use of both quantitative and qualitative approaches in tandem so that the overall strength of the study is greater than either qualitative or quantitative research alone.

Overview of the Design

Two tools, one primarily quantitative (a group-administered questionnaire), and one primarily qualitative (semistructured individual interviews), were used. The group-administered questionnaire (Trochim, 2006) was designed to ascertain the necessary demographics of all participant students and their exposure to the media while avoiding the common disadvantage of a poor response rate (Walonick, 1993). Prior research experience with students of these ages yielded an expectation that repeating and paraphrasing questions in response to direct queries or body language would be necessary to achieve negotiated meaning of the questions. Consequently, a semistructured interview protocol (Creswell, 2005), was the most appropriate method to yield rich qualitative data about students' conceptions about genetics. The mixed methods mode was advantageous in that results from the questionnaire (identifying different levels of media exposure) identified appropriate students to interview (Creswell, 2009).

These two tools were used with multiple samples from widely different regions of Australia. This strategy enabled data collection from a broad spread of the Australian student population in terms of location, cultural backgrounds, and socioeconomic status

(SES), to increase the capacity to generalise the findings to the Australian student population. Consequently, stratified sampling included the following general locations:

- A large urbanized country city (population of 50,000+)
- A midsized country town (population of 15,000 – 50,000); and
- Two small (population of $\leq$ 3,000) isolated rural towns.

In Australia, size of the audience (local population size) determines community access to some media, particularly television. To avoid a possible confounding influence of some sample populations having easier access to all the media available within a state capital city than others, all locations were 650-775 km from their state capitals.

The mixed methods and multiple sample design suited the broad nature of the four research questions as shown in Table 3.1. A summary of the tool(s) used to collect data to answer each question is included.

Table 3.1

Research questions and associated research tools

Research Question (RQ)	Data Collection
1. a) What level of exposure to the mass media do primary students report?	Media questionnaire
b) What specific concepts about genetics are found in the media to which these primary students are regularly exposed?	Purposeful sampling of the mass media nominated by students
2. a) What is the level of primary students' conceptual understanding in genetics?	Semistructured interview
b) What misconceptions do primary students have about genetics?	Semistructured interview
3. From where do primary students believe they have learned about genetics?	Semistructured interview
4. What connections can be drawn between genetics concepts in the media, participating students' reported media use, and their genetics conceptions?	Cross-referencing of quantitative and qualitative data

Data collected for each of the four questions were analysed in both qualitative and quantitative ways. For example, answering Research Question 1 relied mostly upon quantitative data concerning how often and for how long students are exposed to each type of mass media, yet qualitative data about their favourite TV shows and characters was relevant and followed up to address part b). Similarly, Research Question 2 used mostly qualitative data concerning the students' understandings and misconceptions; yet quantitative scoring of their interviews enabled statistical comparison between the location groups. Combining and cross-referencing the two types of data yielded a rich overall picture of the situation.

To address Research Question 4, a range of media exposure was required. Participants in one sample location are likely to show some variation in media exposure, which might connect to different genetics understandings. However, I anticipated that comparison of different locations with known differential access to the mass media would provide a better opportunity to explore such differences. As some small populations currently have access to fewer television channels, some students were not exposed to certain TV shows of interest such as *CSI* and *NCIS*. With Australia poised to roll out digital television over the next few years, which may reduce these access differences, this research was timely.

Finally, the mixed methods multiple sample design is consistent with Firebaugh's (2008) *Seven Rules for Social Research.* Firebaugh states that some of these rules apply solely to quantitative studies; but Rules 3, 4, and 7 apply to this research. Rule Number 3 (pp. 64-82) calls for "built-in reality checks," achieved by collecting different types of data from more than one location. The questionnaire also had built-in internal consistency checks. Firebaugh's Rule Number 4 (pp. 90-109) concerns replication, addressed by the use of multiple samples each subjected to the same analysis. Firebaugh's Rule Number 7 (pp. 207-234) states, "Let method be the servant, not the master." By this rule, Firebaugh (2008) urges researchers to fit the research design to the research issue, not the issue to the design. The application of Rule Number 7 to this research is apparent from this rationale for the selection of the mixed methods multiple sample design.

Participants

Rationale for selection.

Previous work (Donovan & Venville, 2006), indicated that Year 5 students were extremely keen to learn about genes and DNA, and yet were relatively free from some of the misconceptions found in older students. By high school, those misconceptions had become entrenched (Venville & Donovan, 2005b). Therefore, students in Years 5-7 (aged 10-12 years) were selected for this research. It was considered possible that older students within this range may be allowed to stay up later than the younger ones, watching more TV programs such as crime shows, yielding comparisons within each sample.

Research participants.

Table 3.2 outlines the samples and participants in this research. In the larger schools (Samples 1 and 2), the media questionnaire was given to all students who agreed to participate to facilitate selection of an appropriate range of students to interview. The need to avoid disruption of classroom activities restricted interview numbers, especially in Sample 1 where the school made only one day available for interviews. Almost two interview days were available in Sample 2. In the small towns, all students who agreed to participate completed both the media questionnaire and the interview.

At the time of sampling, primary school in most states of Australia was to Year 7, but in New South Wales, primary school ended at Year 6, so it was not always feasible to balance the numbers within each year group in each sample. Town population numbers in Table 3.2 are approximate, utilising the most recent data available, as councils vary in the size of area surrounding the town that they consider part of their population base.

Consulting the My School website (www.myschool.edu.au), particularly the Index of Community Socio-Educational Advantage [ICSEA] supplied for each school, enabled selection for varied SES. The Australian average ICSEA score is 1,000, $SD=100$. The data for a particular year only become available in March of the following year, creating some sampling issues discussed in the next section. The ICSEA data in Table 3.2 include both the value available at the time of sample selection, and the value actually pertaining to the sample year as released later. Sex of participants is shown as girls and boys.

Table 3.2

Samples and participants in this research

Sample	Location in State	Population	Number of schools sampled	School type(s)	School SES status (ICSEA)[2]	Number of participating students						
						Year 5		Year 6		Year 7		Totals
						G[3]	B	G	B	G	B	
1	Inland central Queensland	Large urbanized city, pop. 70,000	One	Old established boarding school	1,014/1,037	15	11	13	11	14	15	79
2[1]	Coastal South Australia	Midsized country town, pop. 15,000	One	New day school (2nd year of operation)	924/1,023	11	3	15	5	6	3	43
3-NSW	Isolated rural outback New South Wales	Small community, pop. 2,500	Two	Very small new school, bigger older day school	718/737	2	3	3	2	1	0	11
3-SA	Isolated rural coastal South Australia	Small community, pop. 3,000	One	Established day school	716/641	2	2	2	0	1	1	8

[1]Note: The distortion in the gender balance reflected the actual enrolments of the school in which females were overrepresented.

[2]Note: The first Index of Community Socio-Educational Advantage (ICSEA) score is the value available when the school was selected; the second score is the value actually pertaining to the sample year as released later (1,000 being average for Australian schools, $1SD=100$).

[3]Note: Sex of participants is shown as G for girls and B for boys throughout this study.

Limitations of sampling.

Interstate research became problematic in public schools due to different state application procedures involving considerable paperwork and lengthy processing delays. This process also entailed obtaining clearance for working with children separately in each state, another time-consuming and costly step. I was already in possession of a working with children police clearance for Queensland (the Blue Card) and private schools in different states were happy to accept this card for a short-term project. Private schools could also make an individual, independent, and swift decision regarding their participation in the research. Thus, for this pragmatic reason, the research sample was restricted to private schools. Private schools may be considered privileged, so care was taken to select schools not overly privileged by their location, resources, or facilities. For example, the socioeconomic status (SES) indicator for the school in Sample 2 was only marginally higher than the public school nearby.

Another limitation was the necessary reliance on outdated ICSEA data to select appropriate schools. When selected, the ICSEA for the school comprising Sample 2 was nearly 1*SD* below that of the school comprising Sample 1, and I planned to pool the data from two isolated areas to form Sample 3. The website showed the three schools in these two isolated areas as statistically similar to each other and nearly 2*SD* below the school comprising Sample 2. These differentials were ideal to give a good spread of SES and to create a larger sample size from two small communities.

However, when the data for the actual sampling years became available, the ICSEA score for the school comprising Sample 2 was higher than expected, reducing the differential between it and that of the school comprising Sample 1. Furthermore, the ICSEA for the isolated school in South Australia had decreased by 75 points, making it theoretically no longer statistically similar to the two schools in the isolated town in New South Wales. The first priority for analysis was therefore to examine the data from these two isolated areas to explore the validity of pooling them. In the interim, they were labelled Sample 3-NSW and Sample 3-SA.

Developing the Research Instruments

Martin (2006) described three theoretical perspectives for asking questions – are the questions seen as standardised for all participants, as a series of cognitive tasks, or as conversation. In this research, the questionnaire was standardised, in a pen and paper format, and the semistructured face-to-face interview deliberately more conversational,

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with the capacity to extend and probe for further information as necessary. Martin (2006) outlined seven principles describing what the respondent to a particular question is expecting and likely to do:

1. Asking a question communicates that a respondent should be able to answer it.
2. Respondents interpret questions to make them relevant to the perceived intent.
3. Respondents interpret questions in ways that are relevant to their own situations.
4. Respondents answer the question they think an interviewer intended to ask.
5. Respondents do not report what they believe an interviewer already knows.
6. Respondents avoid providing redundant information.
7. If response categories are provided, at least one is true. (Martin, 2006, p. 2)

Reference to these seven principles occurs in the following descriptions of the construction of the research instruments.

The questionnaire.

The questionnaire was designed to collect two discreet types of data: necessary personal data about each student (demographics), and data concerning the students' media exposure (to address Research Question 1). The demographics included each student's school year group and specific age, sex, location, cultural background, and whether English is their home language. First names and surname initial only were requested. To disguise real names, each student received an appropriate alias (based on cultural background) upon data entry. Only these aliases appear in this thesis and in all publications. However, using their real first name during the data collection helped to put the students at ease with the researcher, and enabled fruitful conversations with the classroom teacher regarding the students in their class.

To answer Research Question 1, the questionnaire needed to ask, in some way, about the amount of time participants are exposed to each media type, and their favourite examples of each type. Four key considerations arose from the literature: the approach should suit the age of the participants, not be burdensome to complete, have appropriate time scales for the range of media, and designed to minimise skewed results due to perceptions of social acceptability of the answers (Van Evra, 2004). Prior media research, although informative, did not yield any sample questionnaires suitable for collecting the breadth and depth of specific information required for this research. Prior instruments have asked participants to recall the media used in the past week

(Wiman & Newman, 1989), or to keep diaries (Gauntlett & Hill, 1999) but both of these approaches would miss less frequent events such as going to the movies. Consequently, a novel questionnaire was designed for this research, asking participants what they "usually do" with time scales of up to a year. This strategy provided the flexibility for participants to generalise to answers normative for their everyday lives, and to include rare events. From the literature, I predicted that TV would be the main medium to which these students are regularly exposed, so the questionnaire concentrated more specifically on

- the TV shows they watch, their nominated favourite shows and their favourite characters in these shows; and
- If they have ever watched shows such as *CSI, NCIS, Without a Trace, Cold Case, Bones, Find My Family* (termed "TV shows of interest") and if so, how often they watched them, and did they like or dislike these shows.

Questions about participants' usual rising and bedtimes and favourite channels that they and their parents watch were included to cross-link answers with the timing of crime shows, forming an internal check for the consistency of their answers. Most of the questions utilised multiple choice, numerical, or summated rating scales, as these are relatively easy for children to respond to, rather than requiring extended written answers (Waddington, 2000). However, some short written answers were included where I could not predict the range of their possible answers, for example, their favourite shows, E-games, and movies.

The complete questionnaire is reproduced in Appendix B1 as two A4 pages, whereas it was administered to the students as back-to-back A3-sized copies to give them plenty of space. Students of these ages, especially the youngest Year 5 students, typically have quite large handwriting, and it was obvious from the first respondents that a smaller size would have been insufficient and unsuitable. The sheets were colour-coded blue for Year 5s, green for Year 6s, and cream for Year 7s, to facilitate accurate data entry and analysis. Research has shown that coloured paper makes surveys more appealing (Berdie, Anderson, & Niebuhr, 1986).

Mindful of Martin's (2006) seventh principle (at least one answer must be true); students could select *never* if the question did not apply to them. The questionnaire asked students to name "*up to* 3 favourite examples" allowing students the freedom to list none, one, two, or three examples. In the responses, this strategy appears to have

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been successful as students frequently ticked *never*, and some only supplied one or two answers to questions about favourite examples.

The use of *never* also helps avoid the issue of presupposition, which can otherwise lead respondents to answer differently. For example, asking, "which do you prefer, *CSI* or *NCIS*?" presupposes that students have seen both TV shows. Asking students "*which* of these shows have you watched?" and providing a *never* category, forestalls the expectation that they have watched all the shows. This strategy also worked around the issue that some of these shows are not on the TV channels they receive in their community. Most students appeared to understand this question easily, with only some of the younger students asking for clarification.

Martin (2006) commented on ambiguity and the danger of cognitive overload for respondents with detailed questions in which there are conditions added that influence the answer. She pointed out that the best way to deal with this issue is to ask a series of short questions requiring separate answers rather than combining them. Martin's solution guided the construction of the questionnaire so that questions about the crime shows they might have watched, how often, whether they liked or disliked them, and who were their favourite characters in them (if they had favourites) were asked separately.

Martin (2006) showed how, once a respondent has named one thing, they tend to subtract that answer from the next question (the sixth principle). For example, if a student named *The Simpsons* as a favourite TV show and then read another question about favourite TV shows, they would probably not repeat *The Simpsons* but would write about other shows they like. A way to avoid this problem is to move from the general to the specific, so the questionnaire began with all types of media, focused in on television, and then on specific TV shows.

A particular issue raised by Borgatti (1996) and Martin (2006) is the appropriate selection of response categories or scales for each question. There are two obvious, yet commonly occurring problems with scales. First, is the issue of overlapping scales such as 1-10, 10-20, where if your answer is 10, you are unsure of which response to tick. Asking the students about a usual event rather than a specific event, and providing a scale such as *less than 1 hour*, *between 1 and 2 hours*, gave the students freedom to generalise, making the questions easier to answer. The second problem is the use of vague categories such as *most, bit, few,* avoided in this research by using specific categories such as *2-3 times a week* rather than a few times a week.

Asking about usual events that are occurring in their everyday lives also obviated the nine problems of recall that Martin (2006, pp. 7-8) lists. It would have been much less reliable to ask the students what TV shows they recall seeing when they were 3 years old. Students appeared to answer questions about their usual exposure to the media types easily, with the most difficult question being about going to the movies for students in more remote locations that lacked a cinema.

Martin (2006) also cautioned that respondents get a feel for a normative answer from the scale, and that an open-ended answer might be better for the question of "for how long do you usually watch TV?" This issue was the subject of much deliberation but eventually I decided that as the questionnaire included eight different types of mass media, the students might miss open-ended questions, whereas one set of scaled responses should be more obvious. From the extensive literature cited in Van Evra (2004), 2-3 hours of TV is common, but there are reports of some children watching more than 5 hours at a time, so the scale went from *less than one hour* to *more than 5 hours*, with appropriate subdivisions for discriminating between the extremes. That some students ticked *more than 5 hours* indicates honesty rather than a bias towards socially acceptable or normative perceptions of time.

Martin (2006) suggests that questions should be pretested or reviewed prior to use. As well as review by my supervisor, I used the version of the Question Appraisal System (QAS-99) that Willis and Lessler (1999) developed for health studies. Although mainly used for phone surveys, the coding form for questions was very useful for breaking down the required questions, and helping to rewrite them to remove identified problems. Again, mindful of the age range of students and their probable limited prior experience with questionnaires, there were some trade-offs with wording and setting out to make it easier for them to follow. These trade-offs were made with Willis and Lessler's (1999) statements that "there is no such thing as a perfect survey question," and "sometimes we have to 'live with' questions that have some degree of vagueness" (p. 3-2), in mind.

The interview.

To address Research Question 2 regarding student conceptions about genetics, I used the interview protocols from previous research as a starting point (Venville, Gribble, & Donovan, 2005). These protocols were semistructured, in that each respondent received similar questions, but the interviewer could ask further probing questions as required (Creswell, 2005). Previously included questions about theories of

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kinship and biology were not relevant to this doctoral research. The prior study revealed that viewing dogs was a problem for some Islamic students, so I used pictures of cats and kittens as a visual prop to help elicit students' understandings regarding inheritance. The field-testing of these questions in previous research demonstrated their capacity to yield useful data.

To address Research Question 3, I added new questions to the interview protocol to elicit the students' perceptions of the source(s) of information that have contributed to their ideas about genetics. Whenever students made statements indicating they believed the mass media had influenced them, further probing questions ascertained specific media they recollected. Following up such specific media sources for genetics content was important in the context of this research.

Martin's (2006) first principle was a reminder that as some students may not have heard of genes and DNA, it was important to reassure them that not knowing the answer was not a problem. As in prior research (such as Venville, Gribble, & Donovan, 2005), the interview was prefaced by saying, "I don't expect you to know all the answers, I'm just interested in finding out *if* you do know about these things," attempting to remove the expectation of knowledge. Addressing Martin's (2006) fifth principle regarding expertise was more difficult, as clearly I was the expert in genetics. I tried to clarify that it was their *thoughts* that were important, not what they were *sure* they knew as fact. In previous research interviews with this age group (such as Donovan & Venville, 2006), I had noted that students use phrases such as "I don't know, but I think . . ." to separate their thoughts from what they believe to be facts. I generally used words to the effect "only you know what's inside your head and that's what I'm interested in" to explicate this idea.

Questioning techniques gave students opportunity to mention genes, DNA, or chromosomes spontaneously before they were asked if they had heard of these words. The complete interview protocol, accompanying picture sheets and interview record sheets (with answers) is included in Appendix B2, B3, and B4.

Data Collection

From students.

Following acceptance of the research proposal, and granting of ethics approval the following steps were involved in conducting the research and collecting the data.

1. Contact was established and permission gained from Principals and teachers.

2. The school was supplied with information letters and permission/consent forms to send home to the parents of students in Years 5-7.

3. Signed permission/consent forms from parents and students were receipted.

4. Questionnaires regarding the students' exposure to mass media were administered to agreed participants in Years 5-7.

5. A rapid analysis of the questionnaires identified students with high, moderate, and low levels of exposure to the mass media. This strategy enabled selection of a smaller subsample of students for interviews. In small schools with few participants, all students were interviewed.

6. One-on-one interviews were conducted to find out what genetics conceptions students hold, and their perceptions as to the source of the information upon which they are basing their ideas.

Interviews were tape-recorded for later transcription, and matching interview record sheets completed at the time of the interview. These notes were reminders of the topics covered and key answers, helped to make sense later of any words that were garbled on the audio recording, and were used to note visual aspects of the interview (looks of puzzlement for example) which would not be captured by the audio recording. They also acted as a nonverbal cue to the respondent that their answer is important (McKay, 2006). Taking the notes also provided a logical reason from the student's viewpoint for the repetition and/or rephrasing of their answers back to them, which helped me ensure that I had gleaned the correct meaning.

Throughout the research process, I was mindful that it is a privilege, not a right, to enter a teacher's classroom and interrupt their planned program to conduct research. I found Principals and teachers were fascinated by what was discovered about their students. It was not possible to conduct formal interviews with teachers, but informal conversations around the lunch table served as a means to check whether they recalled explicitly teaching genetics to their students.

From the mass media.

There were four purposes for examining the mass media for mentions of genetics such as the terms DNA, genes, and chromosomes. These purposes were; firstly, to inform decisions as to which TV shows to include on the questionnaire, and secondly, how to weight the media data appropriately in the analysis phase. Thirdly and most importantly, to compare ideas to which the students' had been exposed about genetics with their stated understandings of these topics, and lastly, to conduct detailed analysis

of key examples. Pilot media sampling commenced early in the study to achieve the first and second purposes.

To achieve purposes three and four, the unit of sampling was "a mention of a genetics term such as genes, DNA, or chromosomes." There was no specific target population of items such as TV news reports over a fixed period. Such a sampling unit does not lend itself to probability sampling, as the incidence is unlikely to follow any pattern, being very sporadic. Random sampling could miss such mentions in many samples, which would have been inefficient. Consequently, achievement of the third and fourth purposes involved a nonprobability form of sampling known as *purposive sampling* (Trochim, 2006), which Patton (1990) terms *purposeful sampling*.

The specific purposive strategy chosen to achieve the third purpose, ascertaining specific mentions of genetics terms to which the students had been exposed was *chain sampling* (Patton, 1990). In this case, the links in the chain were the media examples mentioned by the students. Most of these mentions occurred in their questionnaire responses, but included any examples mentioned in their interviews. For this strategy, the websites for particular TV shows, especially those that provide detailed synopses, or transcripts, were invaluable. Viewing samples of shows confirmed the accuracy of the website data.

Once the findings indicated which forms of media were key sources of genetics information for the students, the fourth purpose, a detailed analysis of key examples, was achieved by the specific purposive strategy of *intensity sampling* (Patton, 1990). Patton (1990) stated, "The logic and power of purposeful sampling lies in selecting information-rich cases for study in-depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research" (p. 169). In this research, the information-rich cases comprised a few examples of each of the TV shows such as *CSI*, *NCIS*, which often mention genetics topics. It is similar to critical case sampling (Patton, 1990), in which individuals are selected because they can "make a point dramatically" (p. 174). These TV shows were likely to make dramatic points about how this medium handles genetics topics.

Each sample obtained from the mass media had the following characteristics recorded (Altheide, 1996).

- Identification - date, specific medium (such as name of newspaper or TV show), location of sample (such as page number or position in newscast).

- Features - size/length of sample, type of sample (such as advertisement, news, or anecdote), prominence of sample.
- Specific genetics relevance - location of genetics topic (such as headline, body text, picture), a description of the subject matter, how many times specific words such as DNA, genes, chromosomes, alleles were mentioned, the context (e.g. was DNA related to crime, genes to disease), specific comments regarding the correlation between the visual and auditory components (where relevant), obvious factual inaccuracies or omissions.

Selection of television show episodes from recent seasons where possible, increased the likelihood that students had watched these particular episodes. Websites and E-games were researched directly on the Internet. Comics and magazines were researched online, and through the purchase of some physical examples. Some movies were familiar and already in my possession; others mentioned by multiple students were purchased and viewed, but more obscure movies were researched online. My research assistant and I both monitored local radio when we were located in each sampling area. Local newspapers were a special case; I purchased hard copies when I was located in each sampling area, but articles were also available online. As I had collected data in each area at different times of the year, and it was conceivable that this factor could influence the prevalence of genetics-related stories, I also monitored all newspapers local to all the sample areas online for one month towards the end of the data collection phase of the project. This strategy yielded a finite sample for the newspaper articles, enabling the calculations of percentages of incidence of specific topics, as described in full later. I used separate databases for media sample data, media exposure data, and genetics understandings data.

Analysis of Data

This section discusses the specific types of data obtained to answer specific research questions, and indicates how each was analysed. Given the varied data sets collected, many different analytic methods were employed. To facilitate connections between data, analysis, and the findings, I have referred in this section to figures and tables located in Chapters 4 and 5 where I report and discuss the findings. Figure and table numbers are in square brackets. This strategy, although unorthodox, aims to show clearly how each specific analytic method used links to its ultimate output.

In general, the complete data set was analysed first to yield overall patterns, and then, where appropriate, I repeated the analysis for each of the regional samples to probe more deeply for nuances, regional, and individual differences. Five-figure summaries, including minimum, maximum, upper and lower quartiles, and median scores, shown graphically as box-and-whisker plots (Graham, 2010), were useful in several aspects of the analysis [Figures 4.8, 4.14, 4.15, 4.16, 4.17].

Research Question 1 - Media Exposure

1a) What level of exposure to the mass media do primary students report?

Weighting the data enabled conversion from questionnaire responses into real world relative quantities in the spreadsheets. Questionnaire categories such as *every day*, *once a week*, and *once a year* were translated into the numbers 365, 52, and 1. This strategy greatly facilitated calculations that reflected the real differences between these choices. As explained in the following paragraphs, calculation of several different media exposure scores occurred.

The questionnaire asked students about eight different types of media: television, radio, the Internet, E-games, comics, newspapers, magazines, and going to the movies. First, a *frequency score* for each media type, such as 365, 52, 1, reflected how often each participant reported accessing each type of media. Column graphs [Figures 4.1 and 4.2] show the results of counts (converted to percentages) made for all 141 participants for each access frequency for each type of media. Second, *duration scores,* that is, the length of time students said they usually spend when they access each media type, were entered as a score of *one* for one or less hours, a score of *two* for between one and two hours, and so on. Column graphs [Figures 4.3 and 4.4] show the results of counts (converted to percentages) made for all 141 participants for each duration length for each type of media.

An *annual (yearly) score* for participants was calculated by multiplying their media frequency and duration scores for each media type. The annual scores were used to compare participants' average access to the different media types in units of hours per year, as column graphs [Figures 4.5, 4.7, and 4.10]. Comparing the annual scores for the smaller sample group of 62 interviewees with those for the whole sample of 141 participants indicated the interviewees were representative of the total sample [Figure 4.12]. Therefore, the presentation and discussion of most data focused on the

interviewees, although the larger sample was useful for statistical purposes to detect subtle differences in media exposure.

Students' rising times and bedtimes indicated their active hours outside of school time varied considerably, so a novel method was devised to calculate an individual *media saturation score* to consider active hours. The first step was to sum the annual scores for all eight types of media for each participant to get a *combined annual score*. When administering the questionnaire, I directed students to ignore any media exposure in school as this is beyond their control. Thus for each student

- Their rising and bedtimes were used to calculate their average daily active hours. This value was multiplied to calculate their yearly active hours (e.g. if they are active for 13 hr/day then their yearly number is 4745). From this product, the number of hours spent at school over the year (generally 1200, calculated by 6 hr/day x 5 days/week x 40 school term weeks) was subtracted to yield their yearly active hours in which they could be voluntarily exposed to media (in the case of 13 hr/day, that ends up as 3545).

- Each student now had an individual *combined annual score* and an individual *yearly active hours* score. From these scores, the percentage of their active hours that each individual is actually exposed to media was calculated. This *media saturation score* was used for some of the graphs to be presented in the results. The media saturation scores ranged from 3.79 to 124%, providing clear evidence that some students are exposed to multiple media (e.g. TV and the Internet) simultaneously.

The wide-ranging media saturation scores amongst the 141 students were grouped into deciles (0-10.99, 11-20.99, and so on) [Figure 4.6]. To indicate the range of media saturation scores for individuals in each year group, individual scores were sorted from lowest to highest, with the three year groups overlaid [Figure 4.9].

Statistics.

Weighting the media exposure data provided real world estimates of the students' media usage, but posed two main analytical problems. Firstly, the weighted data formed a series of steps rather than being a continuous variable, and the steps did not particularly fit a normal distribution. Secondly, weighting created a very wide range of values, and when considered by year groups, it was possible for one Year group's data to have a more restricted range than the other Year groups. Thus, weighting created

heteroscedasticity, the situation of much larger standard deviations for some groups, and highly unequal variances between the groups. When comparing two groups it was possible to perform a two-sample one-tailed t test that assumes unequal variances, but to compare three groups by an ANOVA assumed normal distribution, and approximately equal variances within the data.

The usual statistical solution to heteroscedasticity is to transform the data. The weighted data most closely approximated count data, for which square root transformation is recommended (Osborne, 2002), and square root transformation proved more effective at normalising the weighted data than either log or inverse transformation. Adding a constant of one removed the problem of data points at zero. In summary, to compare more than two groups, square root transformation readied the data for a one-way single factor ANOVA to see if there was significant difference, pursued between pairs of groups by two-sample one-tailed t tests. With only three groups (such as year groups), only three t tests were needed, avoiding the possible multiplication of error effect that would occur with many groups. The specific type of t test applied to each finding is indicated where reported in Chapter 4 [for example, Tables 4.2 and 4.3]. Cohen's d (Jackson, 2010), was also calculated, when t tests indicated significance, to see the magnitude of the effect. These d values are reported alongside the p values where appropriate in Chapter 4.

Considering average combined annual scores for media exposure for each regional sample against the ICSEA scores indicating SES for each region ascertained possible trends in media exposure with SES. This analysis indicated an overall trend but also highlighted the anomaly of one regional sample, Sample 3, from New South Wales. This anomaly cast doubt on original plans to pool the data of this sample with a similarly remote sample from South Australia. A relative proportion graph [Figure 4.11] clarified the situation. This graph was generated by summing the average annual score for each type of media for the two towns, and calculating the relative percentage of the total contributed by each town sample. This process compared media usage between the towns, and took into account the different sample size in each town; the lack of similarity contraindicated any pooling of data.

The methods just described show how possible relationships between media exposure and other factors such as sex, year group, SES, and location, were explored in the data. These inferential statistics (Trochim, 2006), yielded useful trends and patterns, which collectively produced a rich "big picture" of the situation.

The questionnaire asked students about their viewing of 12 different TV shows, but initial analysis showed that few students had watched two of these, *Insight* and *Weird Science*. Consequently, ongoing analysis focused on the remaining *10 TV shows of interest*, described in Table 3.3. The pilot media sampling informed the third column regarding mentions of genetics terms such as genes, DNA, and chromosomes.

Table 3.3

Brief description of the 10 TV shows of interest in this study

TV Show	Description	Mentions of genetics terms
CSI (also CSI: Miami, CSI: New York)	Crime show focusing on forensics to identify suspects to solve crime	Frequent (DNA), detailed techniques of collection and analysis shown, speed of obtaining results unrealistic
NCIS(also NCIS: Los Angeles)	Crime shows using variety of techniques to solve crime	Often (DNA), some techniques shown, speed of results unrealistic, DNA less featured in *NCIS: Los Angeles*
Bones	Crime show focusing on forensic anthropology	Often (DNA), focus is on result not techniques
Without a Trace	Crime show focusing on finding missing persons	Rarely, focus is on interviews and computer data
Cold Case	Crime show focusing on resolving old cases	Rarely, focus is on tracing past history
Law & Order (also SVU, and Criminal Intent)	Crime shows that depict both the work of police and prosecutors	Sometimes as evidence, focus on evidentiary power of DNA rather than how collected or analysed
The Mentalist	Crime show focusing on solving crime by observation and intuition	Rarely (only 1 episode so far), where switched DNA evidence exonerated the perpetrator
Find My Family	Family-orientated show focusing on reuniting family members	Familial resemblance often commented upon, some mention of genes, genetic health conditions
Can We Help? (the *Lost and Found* segment on about half of the shows)	Family-orientated show where this segment focuses on reuniting family members	Familial resemblance often, genetics, and 3 related episodes over 2009 and 2010 gave accurate information about DNA tests for possible brothers
Who Do You Think You Are	Adult-orientated show tracing family histories	Rarely, the focus is on the paper trail tracing the families of celebrities

The TV shows of interest air in seasons, not every week. Based on the average season length and taking reruns of old episodes into account, viewing frequency of these TV shows was expressed by weighting, with scores of 30, 20, 6, 2, and 0

representing the questionnaire categories *every week*, *most weeks*, *a few times*, *once or twice*, and *never*. Summing the viewing scores of all 62 interviewees yielded weighted viewing scores for each TV show, shown as a column graph [Figure 5.1].

1b) What specific concepts about genetics are found in the media to which these primary students are regularly exposed?

The search of the mass media yielded quantitative and qualitative data in the forms of counts, visuals, and quotes about genetics. In general, this rich source of data passed through three analytical steps: reduction, display, and then drawing conclusions and verification (Miles & Huberman, 1994). Data reduction involved selecting, abstracting, and transforming data into themes by coding (Creswell, 2007). Summaries and tables provided a visual representation of the coded data, assisting interpretation. As principal researcher, I devised the coding schemes as I worked through the contents of the media samples, and an independent coder cross-checked the viability of the coding with 30% of the media samples. The few discrepancies were discussed to achieve consensus. Conclusions were stated as assertions, verified by checking for contradictory data.

The first step was to ascertain the specific media used by the participating students. Each student could nominate up to three favourites of each of the eight types of media; counts were made of each specific example named [Table 4.4]. This table details the three top examples each mentioned by several students, but, where possible, *all* the specific media named by the students were followed up to ascertain their genetics content. Chapter 4 provides summaries of these findings, including descriptions of some media examples and the genetics content found. The intent was to provide a sufficiently thick description (Creswell & Miller, 2000; Bazeley, 2009), to capture the nature of the genetics content in electronic and print media. A separate reference list is provided at the end of the thesis for references to specific media examples described, identified in text and tables with superscript numbers to save space and enhance readability. Tables combine data wherever possible.

Although findings from newspapers are not presented first in Chapter 4, newspapers were the first media samples to be scrutinised for genetics content as the participating students' local newspapers constituted a specific finite sample in which genetics content, when it occurred, was obvious. Newspaper articles were also easy to keep in hard copy for counts, measures, and rechecks, whereas some examples of electronic media (such as transcripts of some TV shows on the Internet), proved to be

transient. Consequently, the 102 newspaper articles found to contain genetics content yielded considerable data, including

- the size of articles,
- associated images,
- location of words about genetics in each article,
- accuracy of explanation,
- grouping articles by theme [Table 4.6],
- specific genetics terms associated with each theme,
- specific examples of nonscientific mentions of genes and DNA,
- relative space allocated to each theme [Table 4.7], and
- regional differences in articles in one month [Table 4.8].

Thematic analysis, also known as conceptual content analysis (Krippendorf, 2004), was used to examine articles containing genetics content (as defined by the inclusion of any genetics term such as DNA, genes, chromosomes, alleles, genetics, and genome). Themes such as solving crime and disease were predictable from pilot sampling, but other content themes including family relationships, genetics of nonhuman organisms, and nonscientific 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 conceptual content analysis. Early in the analysis, it became evident that articles about solving crime mentioned DNA more often than genes. Counts were then made of the incidence of these words in each article. As coding continued, other words such as carrier and mutations were added to the list of words to be counted, ultimately generating suites of words common to each theme. Typology (Patton, 2002), explored the presence of these themes in other genetics-rich media, namely TV shows and magazines, although as these sample boundaries were less defined by time, frequency data were not calculated for these media [Table 5.1].

Genetics content located in the media was rated for scientific accuracy using a simple 5-point scale as shown and exemplified in Table 3.4. Accuracy levels ranged from *none* through to *difficult*, and applied to newspaper articles from all themes. However, as only the theme of disease had articles in all levels of accuracy, this theme yielded the examples for Table 3.4. The same ratings scheme assessed the accuracy of the genetics content of other mass media.

Table 3.4

Accuracy rating for genetics in articles, with examples

Rating	Criterion	Example	Comment
None	No explanation offered	At age nine, Mr Smith's vision started to deteriorate because of Norrie disease, a genetic disorder.	No further information given
Poor	Gross errors of content	With a genome of 368,000 basic pairs, Marseille virus is the fifth biggest virus ever sequenced and has a diametre of 250 nanometres.	Should be base pairs not basic pairs, diameter mis-spelled
Fair	Reasonable attempt to explain at least some terms	Identifying which snippets of DNA contribute to Alzheimer's boosts our understanding of the role of inheritance in its onset, Schellenberg said, adding that others surely remained to be found. But, he added, "the biggest contribution will be in helping to understand the underlying mechanism that causes Alzheimer's. These genes highlight new pathways that are critical to the disease process."	Links genes to pathways but does not clearly link DNA with genes
Good	Adequate and accurate explanation	The trio solved the mystery of how chromosomes, the rod-like structures that carry DNA, protect themselves from degrading when cells divide, an insight that has inspired new lines of research into cancer. The Nobel citation said the laureates found the solution in the ends of the chromosomes - structures called telomeres that are often compared to the plastic tips at the end of shoelaces that keep those laces from unravelling.	Links chromosomes with DNA, provides a good analogy for understanding telomeres, makes it clear it is an analogy
Difficult	Correct explanation but at a very high level or difficult to follow	"MicroRNAs act to block other genes and we were very interested in how they would affect the P53 tumour-suppressor gene. When we started looking at how P53 was regulated … we found one of the microRNAs could block P53, which is a problem because P53 is a tumour suppressor." . . . "The drugs to block these microRNAs are easier to develop than other drugs and one that blocks our microRNA of interest has actually already been developed, so we are keen now to move that drug into clinical trials," he says.	This, with the rest of the article, is a very complex explanation which is not easy to follow as presented

As I was the only genetics expert with access to the data, I made two physical copies of the newspaper articles. The articles were blind-coded twice for scientific accuracy with an intervening interval of six months; the reliability rate of 94% indicated a high level of consistency. The six articles rated differently were positioned between fair and good; ultimately, I assigned three to each group.

Once I had ascertained that television, newspapers, and magazines were the only media types containing genetics content to which most of the participating students had been exposed, a final media score was calculated. This was the *Genetics-Containing Media (GCM) score,* comprising sums of annual scores for only television, newspapers, and magazines, for each participant [Table 4.9]. These scores were subject to similar manipulations as the combined annual scores described earlier.

Intensity sampling involved crime shows and family relationship shows, collectively known as the *10 TV shows of interest,* as described in Table 3.3. Crime shows were analysed separately from the family relationship shows, with consideration given to both visual and spoken messages. Analysis at both general and specific levels occurred, including the transcripts of 10 genetics-related excerpts from four different crime shows. Details are provided in a later section of this chapter, which describes the data analysis methods for Research Question 4.

Research Question 2 - Students' Expressed Knowledge of Genetics
2a) What is the level of primary students' conceptual understanding in genetics?

Discourse analysis is a wide-ranging and complex field, deriving from multiple disciplines such as anthropology, philosophy, sociology, and linguistics, each with its own ideologies and fundamentals (Cameron, 2001). The aim in this research was not to learn more about the nature of discourse itself, but rather to use observations of the discourse as a source of evidence about other aspects of the students' lives. I observed that the interviews were not the question-answer pattern typical of conversation, but the "elicitation-response-feedback cycle" typical of classroom discourse (Cameron, 2001, p. 49). This pattern ensured I had heard the answer correctly, not only in a physical way as in not mishearing words, but also in a "sense" way, as in having grasped the intended meaning. As detailed discourse analysis was not an aim of this study, complete transcription, including all utterances and pauses, was not required. Partial transcription of the interviews, that is, listening to the tapes and filling in notes in the

students' own words around the outlines made on the record sheets at the time, was sufficient to ascertain students' conceptual understandings about genetics.

Each student's interview was scored out of 30 to indicate his or her level of genetics knowledge. Scores for each question were based on the number of ideas expressed (such as uses for DNA) to a maximum of 3, or 2 marks for a fully scientific answer, 1 mark for a partly scientific answer, and 0 for a nonscientific (or absent) answer. For example, the question "What do you think DNA looks like?" was scored 2 if a student's answer included its microscopic size and helical shape (usually expressed as a "twisty ladder," appropriate for this age group), 1 if the answer included either of these criteria, and 0 if neither were included or were in error. These scores provided a convenient, standardised, albeit crude, representation of the interviewed students' knowledge of genetics as a basis for comparison. Appendix B4 contains the interview record sheet, with answers.

Some questions were easy to score, such as whether humans have genes/DNA. However, other responses were open to more interpretation. As principal researcher, I allowed the coding scheme to emerge as I worked through the transcripts, documented it, and completed the coding for aspects of accurate knowledge and the expression of misconceptions. An independent coder then worked through 50% of the interviews using the finalised coding scheme. Intercoder reliability was initially 83%, with most disagreement being about misconceptions (see next section for RQ2b).

The interview scores were analysed similarly to the media saturation scores, by calculating and graphing five-figure summaries as described previously. Sample numbers and distributions thus revealed in the analysis for age (year group) and for socioeconomic status (SES) indicated a nonparametric test was most appropriate. Therefore, a Kruskal Wallis test (McDonald, 2009) was performed. Post hoc Mann-Whitney tests (McDonald, 2009) determined which sample was significantly different from the others. Cohen's *d* (Jackson, 2010) was calculated to determine the effect size.

As previously explained, the interview questions used stimulus pictures of cats and kittens to determine students' levels of understanding inheritance. Based on Venville and Treagust's (1998) model, these levels are, *one*, whether they had any concept of inheritance; that is, that offspring resemble parents through passing of traits rather than simply living in the same place. *Two*, if they have such a concept, whether they understand that traits pass by factors/particles of some kind that physically move from

parent to offspring. *Three*, if they have both ideas one and two, whether they have a genetic understanding. This genetic basis was described as *full* when students spontaneously mentioned DNA and/or genes as a reason why offspring resemble parents, and *partial* in those that did not mention this spontaneously, but claimed to have heard of DNA and/or genes and then made statements linking this entity to inheritance [Table 4.10]. From research (Springer & Keil, 1989; Venville, Gribble, & Donovan, 2005), I expected most, if not all students, should have a basic understanding of inheritance, and that at least some would have further developed a genetic understanding.

Counts were made of the numbers of students 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. These counts were converted to percentages for comparison [Tables 4.11, 4.12, and 4.13]. The counts of answers constitute content analysis, a quantitative approach for qualitative data (List, 2005). This method simplified the identification of patterns and trends in the data. By considering all criteria such as sex, average interview score, and the range of answers for each of the interview questions as summarised in Tables 4.10 to 4.13, it was possible to identify, in an objective way, *typical* students who represented each regional sample (List, 2005). Their voices convey an authentic record of the ways in which they expressed genetics knowledge [Table 4.14].

2b) What misconceptions do primary students have about genetics?

Counts were made of the misconceptions expressed by each student during the interview, based on the list of 24 known misconceptions presented in Chapter 2, now termed K1-K24 to distinguish them from new misconceptions arising in this study. The interview questions did not probe for all 24 known misconceptions. A lack of specific knowledge is not equivalent to holding a misconception, and students aged 10-12, such as those participating in this doctoral research, cannot be expected to have high-level knowledge obtained from formal genetics instruction. Consequently, misconceptions K13-K15 involving terms such as genotype, gene expression and the role of proteins, and K21-K23, concerning dominant and recessive alleles, a detailed definition of the term hereditary, and eugenics did not arise during these interviews. Similarly, K24 concerning cures for genetic disease was not mentioned by any participants. Therefore, these misconceptions are not included in this research.

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The interview questions specifically probed K1, K2, K3, K4, a modified version of K5 (are genes or DNA found in humans), K10, and K12 only, but some student answers indicated they held misconceptions K6, K7, K8, K9, K11, K18, and K20. Some students expressed novel misconceptions; these were assigned M numbers, ultimately, M1-M18. Total misconception counts therefore represent the number of misconceptions expressed against K1-K12, K18, and K20, plus any novel misconceptions expressed.

Students were counted as having misconception K12 (knows that genes have a function but does not know what that is), only if it was obvious that they knew of a function but could not describe it, or gave an incorrect answer such as controls blood sugar. I did not count students who had no idea that DNA/genes had a biological function as having misconception K12; most of these students expressed misconception K3, believing DNA's function is to be shed at crime scenes. Some variants to the known misconceptions were also noted, for example, a subgroup of students expressed a variant of K4 (regarding the location of DNA in blood and other body parts collected for forensics), in believing that genes or DNA were restricted to only a few internal organs. Such variations are noted in the results. The literature is divided as to whether the notion of inheritance due to factors/particles being passed from parent to offspring is a stage or level of understanding about inheritance (Venville & Treagust, 1998), or whether it is a misconception (K10) (Lestz, 2008; Lewis & Kattman, 2004). Therefore, in this research, I counted it both ways: as a stage of understanding about inheritance in Table 4.10, and as misconception K10.

Misconception counts were compared on a regional basis [Figure 4.17]. To see if there was a trend connecting genetics knowledge and genetics misconceptions, the counts of misconceptions were plotted against genetics knowledge scores with 95% confidence limits [Figure 4.18]. Key misconceptions shared by many students, such as thinking that DNA is only found in the blood or body parts collected as forensic samples, were examined in more detail [Table 4.15]. The incidence of all known (K) misconceptions was summarised [Table 4.16], and of all new (M) misconceptions [Table 4.17].

Again, content analysis (List, 2005), identified students typically expressing misconceptions. To account for the trends just described, two tables are presented: the statements of four boys all in Year 5, each typical of their regional sample [Table 4.18]

and four diverse students who had higher genetics knowledge scores for their region [Table 4.19].

As noted in the discussion of RQ2a), intercoder reliability was 83%; that is, 17% disagreement, when scoring the interview. This disagreement mostly concerned which misconception students were actually expressing. Some misconceptions are very similar; for example, in some students' statements it was difficult to distinguish between a belief that a gene *is* the trait, and a belief that there is a gene *for* a trait. The two coders discussed these examples to achieve consensus.

I revisited the data often to avoid bias such as adhering to first impressions. Ultimately, I had intimate knowledge of the nuances of each interview. This knowledge confirmed the typicality of the students selected by content analysis for inclusion in Chapter 4. This knowledge also facilitated the selection of specific student statements to illustrate the genetics concepts derived from the media in Chapter 5. In the midst of the useful quantitative data, it was essential that the voices of the students be heard in this research.

Appendix D presents abstracted comments that students made about DNA and genes during their interviews. These comments were combined from the answers to various interview questions, particularly spontaneous comments from question 4 (about inheritance), and answers to questions 6 (about the location of DNA), 11 (about their sources of genetics knowledge), and 12 (about the uses of DNA outside the body). The statements are generally verbatim, but with most repetitive utterances such as "ah" and "um" removed, and occasional linking words added to enhance clarity. When read as a totality, these *reduced data* provide a powerful impression of the breadth and depth of genetics knowledge, and the sources to which the participating students attribute this knowledge.

Research Question 3 - Students' Perceptions of Information Sources

From where do primary students believe they have learned about genetics?

This question was asked towards the end of the interview, deliberately separating the students' biological knowledge of genes and DNA from their knowledge of what these entities may be used for outside the body. Students were asked to volunteer information, and then asked about specific categories they had not mentioned. I noted which sources students mentioned spontaneously and which were prompted. The sequence in which students mentioned particular sources was also noted, on the basis

that the first mentioned is likely to be most significant to them. The interview record sheet had the categories of *parents, school, reading, TV*, and *other*. However, the students' responses allowed the creation of two new categories; *news*, combining input from TV and newspapers, and *own research* via the Internet.

To compare the responses from all four regional samples, these data are presented as a stacked column graph [Figure 4.19]. Informal conversations with teachers in the schools confirmed that no formal genetics tuition had taken place, although students appeared to recall casual classroom conversations. Student interviews were scrutinised for specific television shows mentioned as sources in response to this or any other question, and counts made [Table 4.20].

Research Question 4 – Interconnections

What connections can be drawn between genetics concepts in the media, participating students' reported media use, and their genetics conceptions?

This research question required intensive cross-referencing and constant comparative analysis (Creswell, 2005) of the data sets. The findings of this process are presented in Chapter 5. Firstly, the commonality of genetics themes that emerged from analysis of newspaper articles to other known genetics-containing media (television and magazines) was established [Table 5.1]. Then the genetics themes from the media were compared with student statements about genetics, and cross-tabulated to show commonality [Table 5.2]. The rank order of incidence of these genetics themes in a finite media sample (newspapers), and the student statements were compared [Table 5.3].

In particular, the *10 TV shows of interest* (as described in Table 3.3), were examined in terms of their genetics content and viewing by participating students. A column graph indicates the relative viewing of these TV shows, despite some of them being unavailable free to air in all areas [Figure 5.1].

The discourse in the crime shows of interest was analysed at a general level by applying Hymes (1974) SPEAKING grid to the discourse in 10 examples. Similarities were such that a single generalised grid was derived [Table 5.4]. The visual aspects of these crime shows, particularly the equipment seen to be associated with genes and DNA, were examined [Tables 5.5 and 5.6]. Chapter 5 also includes a critical commentary, substantiated by research, of the accuracy of the visual aspects of these TV shows. Transcripts of genetics-related excerpts of 10 episodes (three each of *CSI, NCIS,* and *Bones*, and one of *Law & Order*), were analysed in depth. Three such

transcripts are reproduced in full in Chapter 5; others are described. Cross-matching transcripts with statements made by participating students during their interviews connect specific information available in the media with specific words from the students. These connections are supported by critical comment and reference to research where necessary. Purchasing copies of these crime shows enabled me to revisit the excerpts several times during the analysis.

Four possible interconnections between student viewing of crime shows and their linking DNA with crime arose during the analysis. Students could be

- viewers of crime shows who link DNA to solving crime,
- nonviewers of crime shows who do not link DNA to solving crime,
- nonviewers of crime shows who link DNA to solving crime, or
- viewers of crime shows who do not link DNA to solving crime.

Specific students placed into these four categories are listed [Table 5.7].

Family relationship TV shows differed from the crime shows in being more generalised, and more narrative in style and discourse, rendering Hymes (1974) grids unhelpful. The cancellation of two family relationships TV shows, *Find My Family,* and *Can We Help?* during the course of the research was an unexpected complication. These shows were not available to purchase, so I could not revisit episodes as was possible for the crime shows. Episodes of *Find My Family* were removed from the Internet, but transcripts of the episodes of *Can We Help?* remained available online. This availability assisted the processes of data collection and analysis. I was able to compare some student comments with specific genetics concepts noted in these family relationship television shows when aired.

Examination of students' motivations for viewing particular television shows was possible by analysis of student favourites [Table 5.8]. This information is cross-tabulated with students' genetics knowledge, particularly their linking of DNA with crime, and perceived sources of information [Table 5.9]. Student responses were also cross-tabulated to link their genetics knowledge scores with their naming of particular characters from the crime shows of interest as favourites [Table 5.10].

The possibility of a relationship between students' genetics knowledge and the number of sources of genetics information that they acknowledge, was explored by grouping students according to the number of sources they mentioned, and finding the average interview score for each group thus created [Figure 5.2]. Content analysis

(List, 2005), enabled the objective identification of students typical of each group based on the criteria of number of sources mentioned, average interview scores, and numbers of genetics misconceptions. The voices of these identified students are presented as an authentic record of typical understandings [Table 5.11].

Another connection was sought between students who claimed to have researched genetics themselves and their level of genetics knowledge overall, compared with students who had not done such research. Average knowledge scores and number of sources mentioned were calculated for both groups. A subsample size of 17 is marginal for a t test but Chapter 5 presents the resultant p value, and Cohen's d (Jackson, 2010), calculated for effect size [Table 5.12].

Collectively, these interconnections covered the major possible links between the various data sets in this research: the media exposure data, the genetics concepts in the media data, the genetics knowledge data, and the perceived sources of genetics knowledge data, at both general and detailed levels.

Synthesis of Data

The conclusions from the findings presented throughout Chapters 4 and 5 are summarised to yield 78 assertions. These assertions were grouped into figures in Chapter 6 to facilitate data synthesis: the connection of ideas into single statements. Thus, from Figures 6.1 to 6.6, 20 meta-assertions were derived. Finally, the meta-assertions about the mass media and those about the participating students are shown juxtaposed in Table 6.1. This process aided the development of an on-balance judgement of the possible influence of the mass media on the genetics understandings of the students. Discussion of this synthesis in the light of the three theories of media influence detailed in Chapter 2 elucidates possible mechanisms for the influence inferred from the findings.

<div align="center">*Trustworthiness*</div>

"All field work done by a single field-worker invites the question; why should we believe it?" (Bosk, 2008, p. 167). This research addressed issues of trustworthiness in the following five ways.

1. *Triangulation.* This involves using more than one approach to solve a problem, and may refer to sources, methods, theories, investigators, or paradigms (Denzin, 1978; Janesick, 1994; Patton, 2002). This research employed four forms of triangulation.

- Theory triangulation. By considering the explanatory power of three theories of media influence for the findings of this research.

- Methodological triangulation. Multiple methods, including quantitative and qualitative methods were used.

- Data triangulation. Involving four different regions, five different schools, multiple students at each location, and multiple sources of information for each student.

- Interdisciplinary triangulation. Working within the disciplines of science, education, and media studies.

Given the nature of this doctoral research, it was generally inappropriate to use investigator triangulation (Denzin, 1978; Patton, 2002). However, use was made of a research assistant as a blind coder where appropriate and other methods, such as blind coding the same data set again after a substantial time delay, also sought to test the reliability of the coding scheme.

2. *Descriptive validity.* This involves accuracy, issues of omission, and noting events not captured by the audio recording (Maxwell, 2002). From Padgett (1998), it also involves considerations of threats to trustworthiness, including reactivity (effects of the researcher's presence), researcher bias (leading questions, ignoring data), and respondent bias (withholding information to protect themselves, or being overly helpful and saying what they think the interviewer wants to hear). In this research, descriptive validity was attained by

- Accuracy. Notes were written as the interview proceeded to capture expressions not recorded on tape (Maxwell, 2002). I repeated back what I heard to ensure I accurately captured the student's intended meaning. This strategy gave rise to an elicitation-response-feedback mode of communication (Cameron, 2001), to ensure I had captured not only *what* was said but also what was *meant* by what was said.

- Researcher bias. My interview questions were independently assessed.

- Reactivity. I ensured that I had opportunity to meet the children as a whole class prior to conducting the interview. I chatted a little with students before the interview began to put them at ease. I found the students easily ignored the tape recorder after the initial introductions, and nearly all were forthcoming with their ideas as well as with their knowledge. The students were overwhelmingly pleased to be involved in research, and excited by the

thought that someone considered their ideas important enough to be captured and used to inform other teachers and researchers.

- Respondent bias. No particularly personal questions that might tempt the children to lie or withhold information for self-protection were included. In addition, asking students to fill in the questionnaire first, before asking them about their conceptions about genes and DNA, avoided the students filtering their answers about the media in the light of what they might think I wanted to hear about genes and DNA.

3. *Avoidance of intuitive data processing (IDP) biases* (Sadler, 2002). This included

- Records. Recording all coding decisions, using blind check methods.
- Checking. Revisiting raw data repeatedly, even when I believed I knew the data intimately, so that any statement or conclusion was rechecked and confirmed with the actual data.
- Including all data. Consciously looking for disconfirming evidence (Miles & Huberman, 1994), also termed negative cases (Patton, 2002; Bazeley, 2009), to avoid unconscious selection of information that confirms the hypothesis, and not noticing or undervaluing disconfirming evidence. I combed the data multiple times, and it was while searching for disconfirming evidence that I became aware of a group of *viewers but nonlinkers*, that is, students who viewed television crime shows but who did not link DNA to solving crime. One of these students, Jemilia, watched more crime shows than any other individual student, being an outlier in terms of her television viewing, and yet knew very little about DNA. This negative case could subsequently be explained, along with the rest of the viewers but nonlinkers group, by literature reporting different mental effort and motivations for viewing such television shows.

4. *Rigour.* This was enhanced through peer review (Allende, 2012), as follows

- Statistics. A statistician was consulted during the design phase, and again during the initial analysis of the data. A different statistician was consulted at the conclusion of the analysis as a cross-check, and to ensure that the most appropriate statistical tests and ways of displaying the data had been used.
- Feedback. Work in progress was presented for critical feedback at three conferences of the Australasian Science Education Research Association (ASERA) (Donovan, 2010; Donovan & Venville, 2011, 2012c), and to two

other university-based seminars. In addition, my supervisor gave a keynote address on this doctoral research in Germany (Venville & Donovan, 2012), which generated considerable interest and feedback.

- Peer-reviewed publication. Two papers have been published so far based on this research, both in special issues of peer-reviewed journals. One considered a subsample of the participants (Donovan & Venville, 2012b); the other was a substantial paper of some 20,000 words, based on the thematic similarities of genetics concepts in the media and in the students' responses (Donovan & Venville, 2012a). The three reviewers for the latter paper were particularly helpful in demonstrating how international readers might respond to the work, and providing insightful comments that improved that paper, and were applied to this thesis. Several more papers are planned with provisional titles for a range of journals.

5. *Audit trail*. I am a methodical person, so readily created an audit trail and a journal documenting my journey through the research process, demonstrating a spirit of openness to enhance reproducibility (Padgett, 1998). The audit trail records the process of this research, including all raw data, all coding decisions, analysis decisions, statistical decisions, and the basis for the synthesis of the data into 20 meta-assertions.

Ethics

The research was conducted ethically in accord with the Human Research Ethics Committee of the University of Western Australia (RA/4/1/2516), who were updated with progress annually as required. The parents of proposed participants received a letter outlining the purpose of the research (Appendix C1) and a permission/consent form (Appendix C2) that both they and their child were required to fill in and sign permitting involvement in the research. Using aliases throughout the research from data entry onwards ensured I forgot the real names of participants, making accidental use of their real name when reporting findings highly unlikely. Given the number of participants and the data collected, it is less likely that they will be recognisable or identifiable than if they had been the subjects of a detailed ethnography. I have not disclosed the exact locations or names of schools, thus taking all possible steps to protect participants' confidentiality and anonymity.

Chapter Summary

> A historical antagonism between the proponents of qualitative fieldwork
> and of survey research has prevented recognition of the benefits to be
> gained by employing both methods in the same study. Each method can
> be greatly strengthened by appealing to the unique qualities of the other.
> Through examination of a number of cases in which the methods have
> been integrated, it is possible to discern important benefits in design, data
> collection, and analysis. (Sieber, 1973, p. 1335)

This quote from Sieber epitomises the strengths and benefits of a mixed methods mode of research, ratifying the selection of this mode for this study. This exploratory research would have been impossible without incorporating both quantitative and qualitative data. The initial analysis of the quantitative data raised questions and ideas that were then probed in the qualitative data. The process of analysis was iterative, with continual movement between the types of data to elucidate ideas, inferences, and to enable conclusions to be drawn. The strength of the study is in the capacity to cross-correlate both types of data.

As detailed in this chapter, the research tools were original, designed specifically to capture the data required by this study, but based on extensive research in order to substantiate their validity. Research and specialist advice in the case of statistics guided the selection of analytical methods. This chapter contains detailed descriptions of the research tools and analytical methods in the spirit of openness to enable others to replicate the research. Considerable care was taken to enhance the trustworthiness of the data and hence the findings from the analysis and synthesis of the data.

As always, repetition of the study could result in improvement of some aspects. More schools, being able to access public schools, larger sample sizes, more interviews – more data always appears to be desirable. Yet there is a danger that the more data that is obtained, the more it becomes overwhelming, and the detail is lost. The data collected for this study has been sufficient to show interesting patterns, trends and to allow some bounded conclusions to be drawn, without losing sight of the individuals that comprised my samples.

Chapter 4 – Findings and Discussion of Research Questions 1, 2, and 3

This chapter presents the data collected for the first three research questions, which address the participants' media exposure, genetics knowledge, and perceived sources of this knowledge. Research Question 4 involving the interconnection of these aspects of the study is addressed in Chapter 5.

The data were analysed first as an Australian data set for general trends and patterns, and then for regional variations. All 141 students from Years 5, 6, and 7 completed the media questionnaire, and interviews ascertained the genetics knowledge and perceptions of sources of knowledge of 62 students. Results for Research Question 1a), concerning media exposure, utilised the larger data set for the most part, then the rest of the analysis was based on the subset of interviewees.

Findings

Research Question 1 - Media Exposure

1a) What level of exposure to the mass media do primary students report?

Level of exposure to the mass media was assessed in several ways. As detailed in Chapter 3, these were *frequency*, that is, how often each medium is accessed; *duration*, that is, for how long a time; combining frequency and duration into *annual scores* to get an overall picture; and *saturation* level, that is, how much of their free time do participating students choose to spend with the mass media.

The first measure was to consider the *frequency* with which students interact with various forms of the mass media. Figure 4.1 provides these data for the electronic media (TV, Internet, radio, E-games), which are the more frequently accessed forms of the mass media. Figure 4.2 provides these data for the print media (comics, newspapers, magazines) and for movie attendance, the less frequently accessed forms of the mass media. Both Figures 4.1 and 4.2 show data for the full sample of 141 students converted to percentages for ease of comparison.
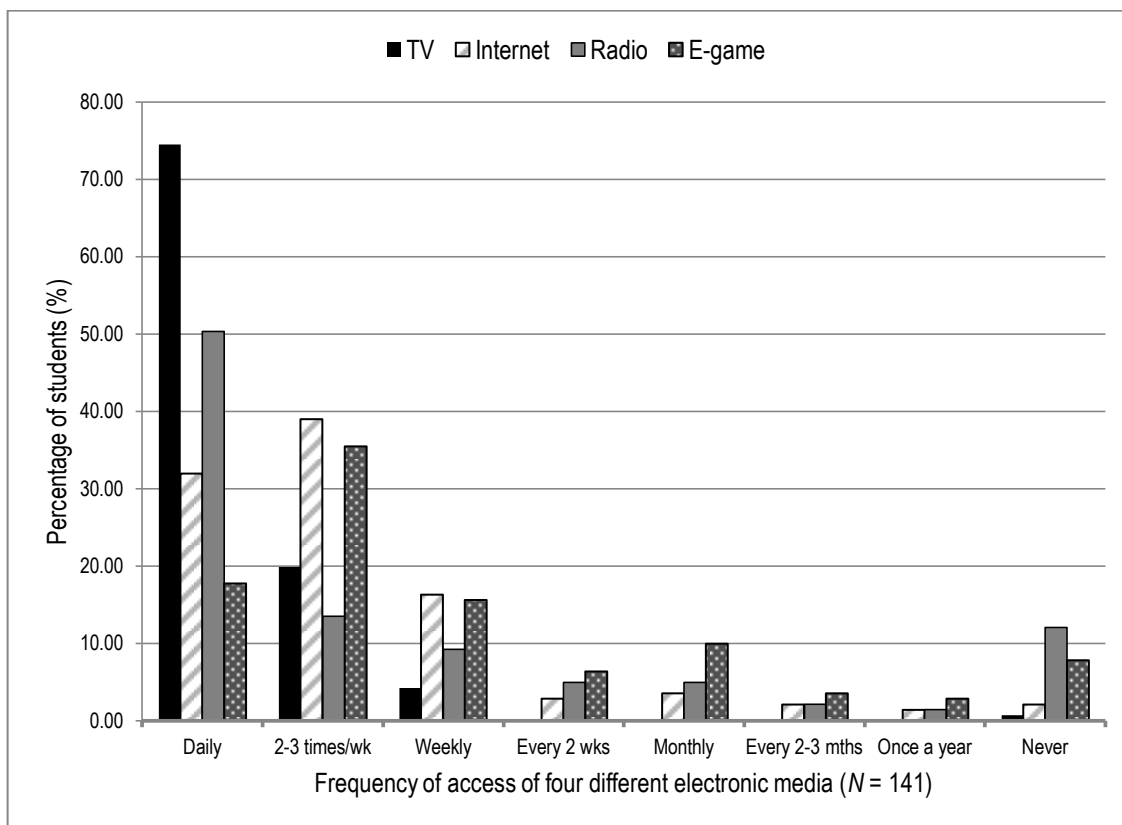
Figure 4.1. Frequency of use of electronic media by whole sample (*N* = 141).
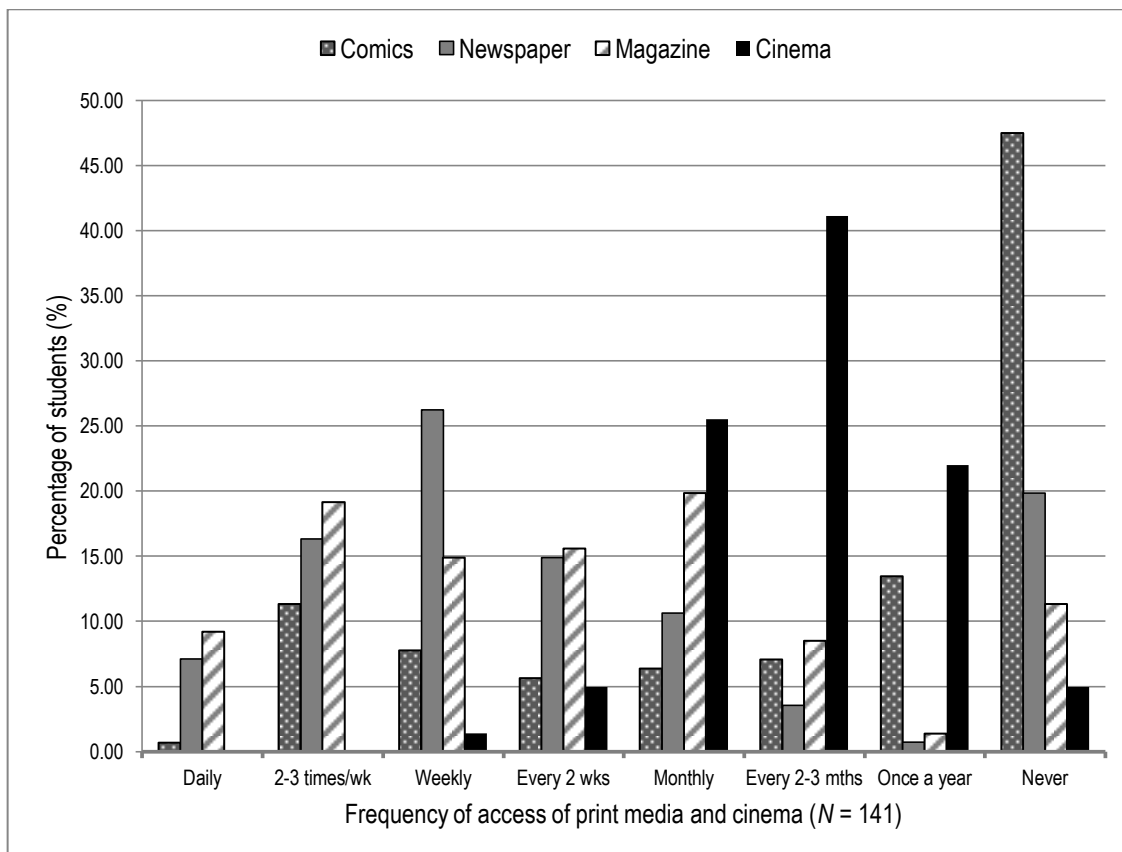
Figure 4.2. Frequency of use of print media and cinema by whole sample (*N* = 141).

Figure 4.1 shows that TV is the most frequently accessed medium, with 75% of participants accessing it daily, 20% accessing it 2-3 times a week, and only one student claiming never to watch TV. Internet access levels were greater than expected from the geographic locations of the participating students, with 32% accessing it daily, and 39% accessing it at least 2-3 times a week. Only five percent access it less than monthly or never. Despite perceptions of radio as a dying medium, these students accessed it regularly; with 50% using it daily, although compared with the other electronic media, a higher percentage (12%), never listen to radio. Students commented that much of their time spent with the radio is in the car, particularly when they travel to and from school. The most typical frequency of use of E-games, a relatively new medium, was 2-3 times a week.

Figure 4.2 shows that comics have a few regular fans, but are the medium with the greatest percentage of students (nearly half), that never access them. Students accessed magazines slightly more often than newspapers. Going to the cinema is the least frequent media interaction for these students, with 41% of the students making about five visits per year. Of the sample of 141 students, 79 live in a city with six cinemas, 43 live where there is one cinema, and only 19 students live in towns that lack cinemas. Table 4.1 shows attendance percentages for these regions, indicating that although lack of access to any cinema clearly makes a difference, students with access to more cinemas do not attend them proportionately more often. This situation is not due to disinterest in movies, as in all, 149 different movies were nominated as favourites. Although 69 of these movies had been in cinemas within six months of data collection (such as *Twilight* and *Avatar*), others were older, ten being 1970s classics such as *Monty Python, Apocalypse Now, Grease,* and *Jaws*. These data collectively indicate that students typically watch movies at home, via purchased or rented videotapes or Digital Versatile Discs (DVDs), or possibly on the Internet.

Table 4.1

Effect of cinema availability on percentage frequency of student visits to cinemas

	Weekly	2 weekly	Monthly	5/year	1/year	Never	Total
6 cinemas ($n = 79$)	2.5%	3.8%	27.8%	44.4%	19%	2.5%	100%
1 cinema ($n = 43$)	0	9.3%	25.6%	41.9%	18.6%	4.6%	100%
0 cinema ($n = 19$)	0	0	15.8%	26.3%	42.1%	15.8%	100%

The second measure of media exposure is the typical *duration* of each interaction. Figures 4.3 and 4.4 provide duration data for the same groupings of mass media forms as for the frequency data. Again, data for the whole sample of 141 are shown, converted to percentages.
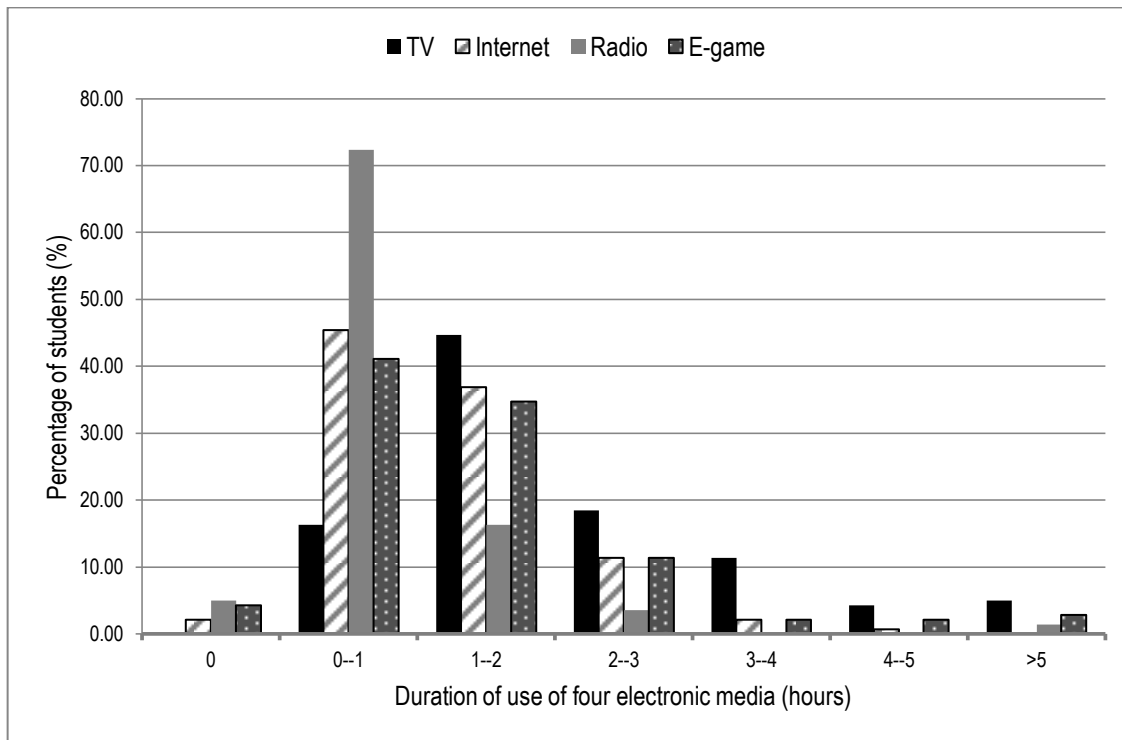
Figure 4.3. Duration of use of electronic media by whole sample (*N* = 141).
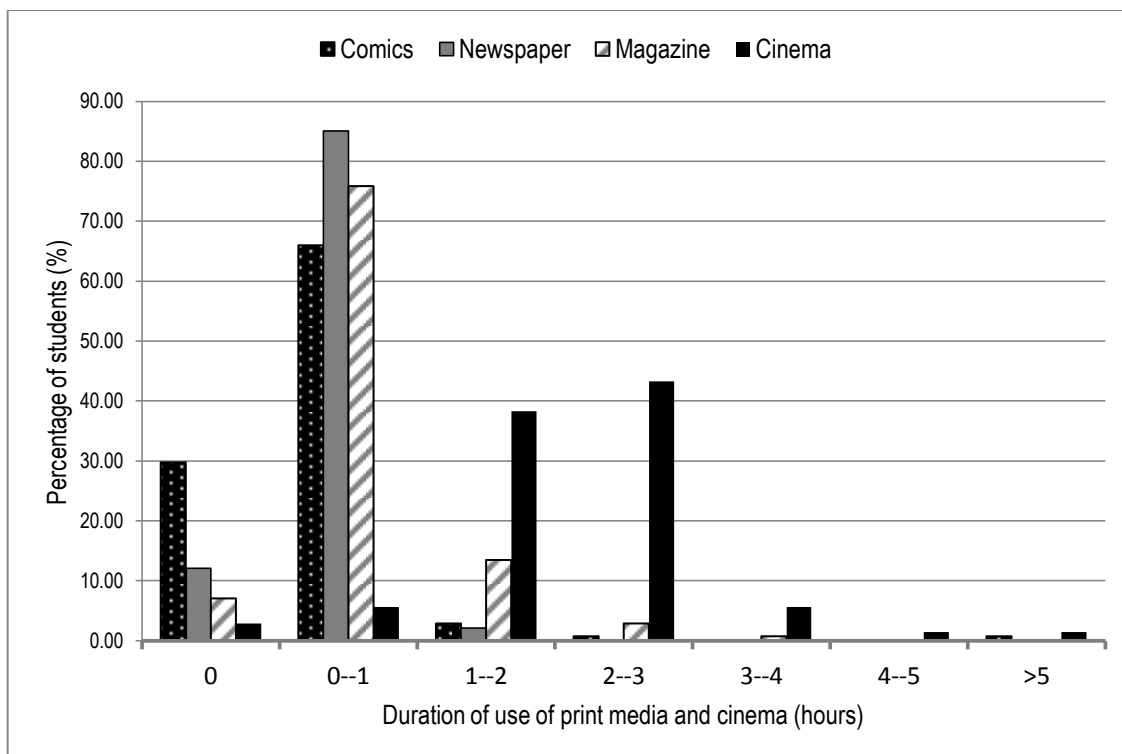
Figure 4.4. Duration of use of print media and cinema by whole sample (*N* = 141).

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Figure 4.3 indicates that TV has the highest self-reported duration of use, with over 50% of students watching for up to two hours each time. Remaining students reported watching TV for longer, with five percent admitting to watching more than five hours at a time. Students usually use the Internet for up to two hours at a time, with longer durations being rarer than for TV, and no students reporting using it for more than five hours at a time. Students often use radio, but typically for only one hour at a time, consistent with comments about it being on in the car. E-games have a range of perceived duration of use, with 40% spending only an hour with them, but three percent admitting to playing them for more than five hours at a time. Figure 4.4 shows that the print media are ephemeral, typically remaining in the students' hands for less than one hour. Most students (81%) accurately estimated the typical time they spend at the movies (1-3 hr), despite this being their least common media interaction.

Combined frequency and duration scores create an *annual score*, indicating the relative total usage of each form of mass media over a year. Figure 4.5 shows the average annual scores for all types of media for all surveyed students ($N = 141$).
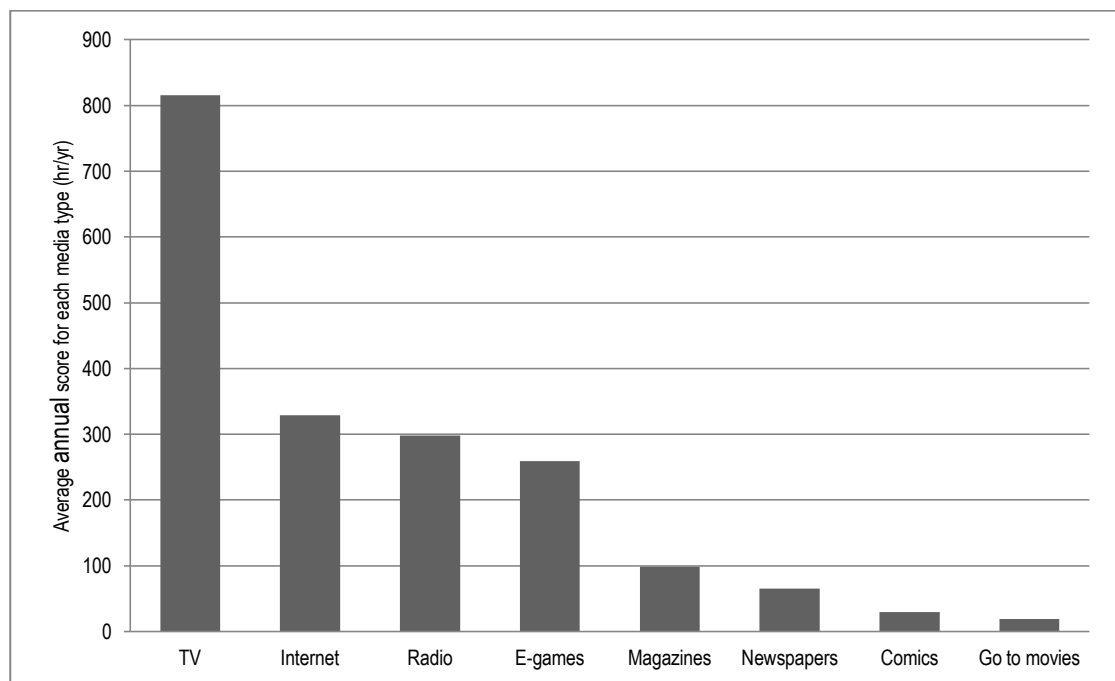
Figure 4.5. Average annual scores for all media for the whole sample ($N = 141$).

Figure 4.5 clearly shows how TV is the most accessed medium, and how much less students access the print media compared with the electronic media. This finding implies that television is likely to have a greater influence on students than any other single form of media. These data collectively lead to two assertions regarding the participating students' use of the mass media.

Media Assertion I: Participants accessed television 2.5 times more than any other form of mass media.

Media Assertion II: Of the print media, participants accessed mostly magazines and newspapers.

To elucidate the distinction between long days of media use or using multiple media at one time, a way of assessing each individual student's use of media compared with the amount of time available to them outside of school time was required. Therefore, a novel index of media exposure as a percentage saturation of their individual waking out-of-school hours was calculated, with scores near to and exceeding 100% saturation indicating use of multiple media at one time. Chapter 3 gave details of the precise method of computation of this *media saturation score*. Deciles show the spread of the media saturation scores in the whole sample, as seen in Figure 4.6.
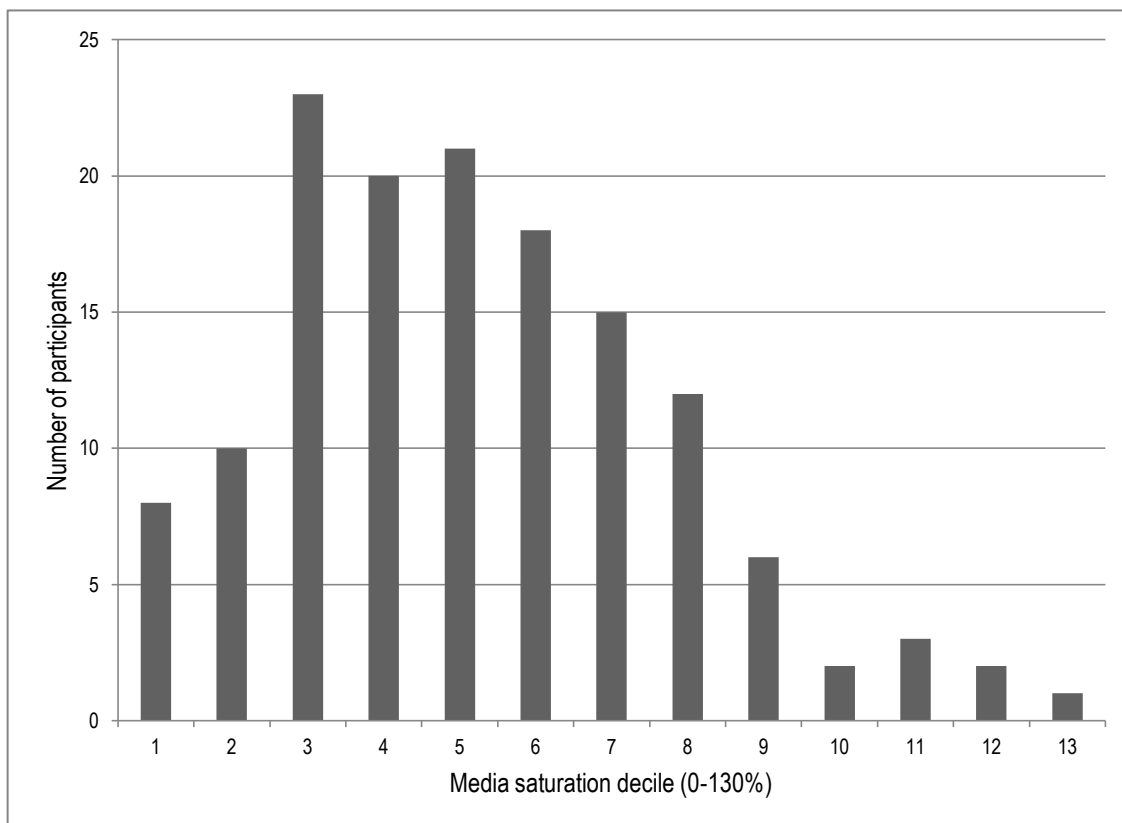
Figure 4.6. Number of participants (*N* = 141) per decile of media saturation scores.

Figure 4.6 shows that the distribution of media saturation scores was skewed slightly to the left, with most participating students within deciles 3-8, that is, spending between 30-80% of their available time with the media. There were a few more very low users (≤ 20% of their available time with the media), than very heavy users (≥ 90% of their available time with the media). Comparison of averages and standard distributions must take into account this wide range of scores.

Annual score data as in Figure 4.5, and media saturation score data as in Figure 4.6, were used to interrogate the data set for the influence of sex, age, and socioeconomic status (SES) on students' media access.

Sex.

Figure 4.7 presents the average annual scores for each media type by sex, and Table 4.2 shows the significant differences between the sexes as assessed by two-sample one-tailed heteroscedastic t tests at the .05 level of significance.
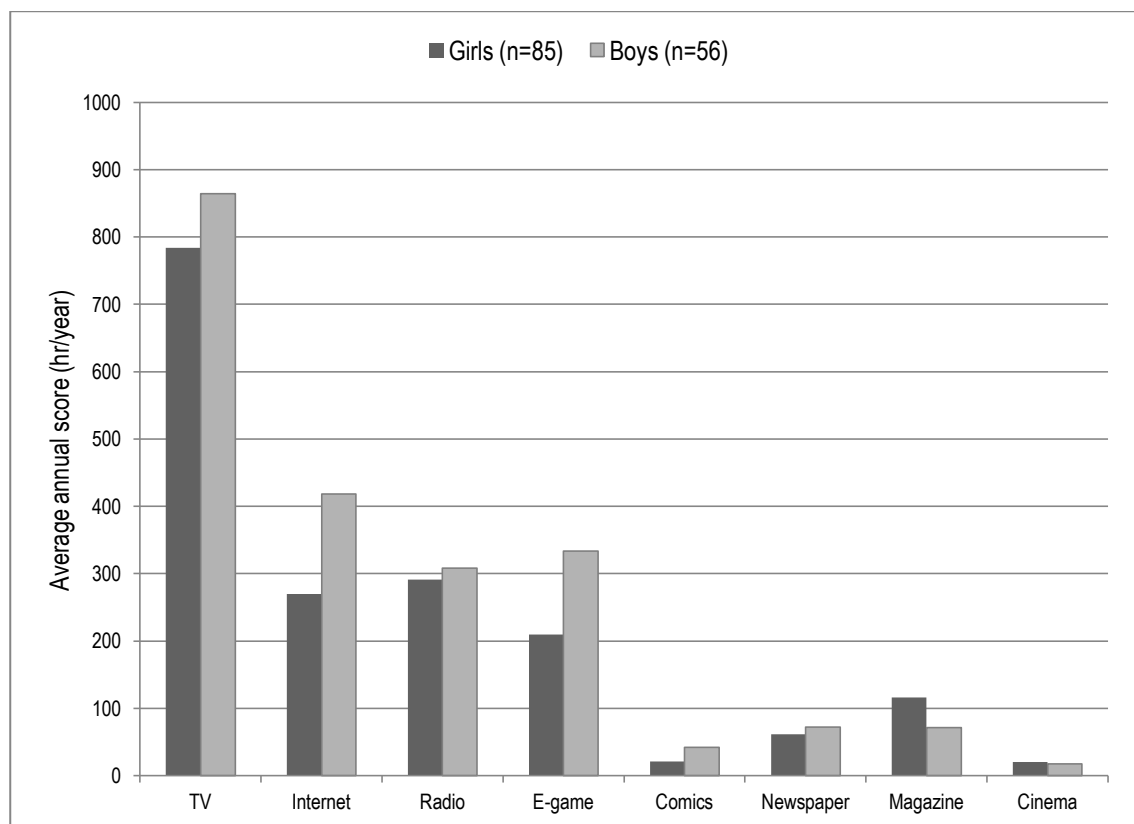
Figure 4.7. Different media usage (annual scores) by sex (85 girls, 56 boys).

Table 4.2

Significant differences in media usage (annual scores) by sex (56 boys, 85 girls)

Significant difference	Boys		Girls		*p*	Cohen's
	M	*SD*	*M*	*SD*	values	*d*
Boys use more media	2,128.41	1,098.77	1,773.75	854.29	.022	.36
Boys use more Internet	418.63	380.85	269.53	294.08	.007	.43
Boys play more E-games	334.00	360.95	209.89	320.32	.019	.36

Boys use more media overall, the combined average annual scores representing a mean of 5 hr 50 min per day, compared with 4 hr 51 min per day for girls. However, scores were wide-ranging, from 52 min to 13 hr 19 min for boys, and from 24 min to 11 hr 5 min for girls. Figure 4.7 shows that boys use more of all media types except magazines and cinemas, though only the Internet and E-games achieved statistical significance. As Cohen's *d* values approach medium effect size (.5), these differences are not trivial (<.2).

> **Media Assertion III: In terms of total media usage, participating boys used significantly more media than girls.**

Daily averages in excess of 11 hr indicate students are probably using multiple media at one time. Sorting media saturation scores by sex clarified which of the sexes were choosing to use multiple media more often. Five-figure summaries, shown graphically as box-and-whiskers plots in Figure 4.8 for girls and boys, present these data visually.

Figure 4.8 shows that at least some students at the top end of the ranges must be using multiple media at one time, with the maximum media saturation scores being 103% for one girl and 124% for boys. Five boys had scores in excess of 100%. In practice, it is unlikely that a student's every waking moment would be occupied by media, as some daily activities such as personal hygiene tasks are less conducive to continuing use of the types of mass media surveyed. Thus, it is likely that students with scores near to 100% would be using multiple media on some occasions. Therefore, not only do boys use more media than girls overall, they also choose to use multiple media at one time more often.
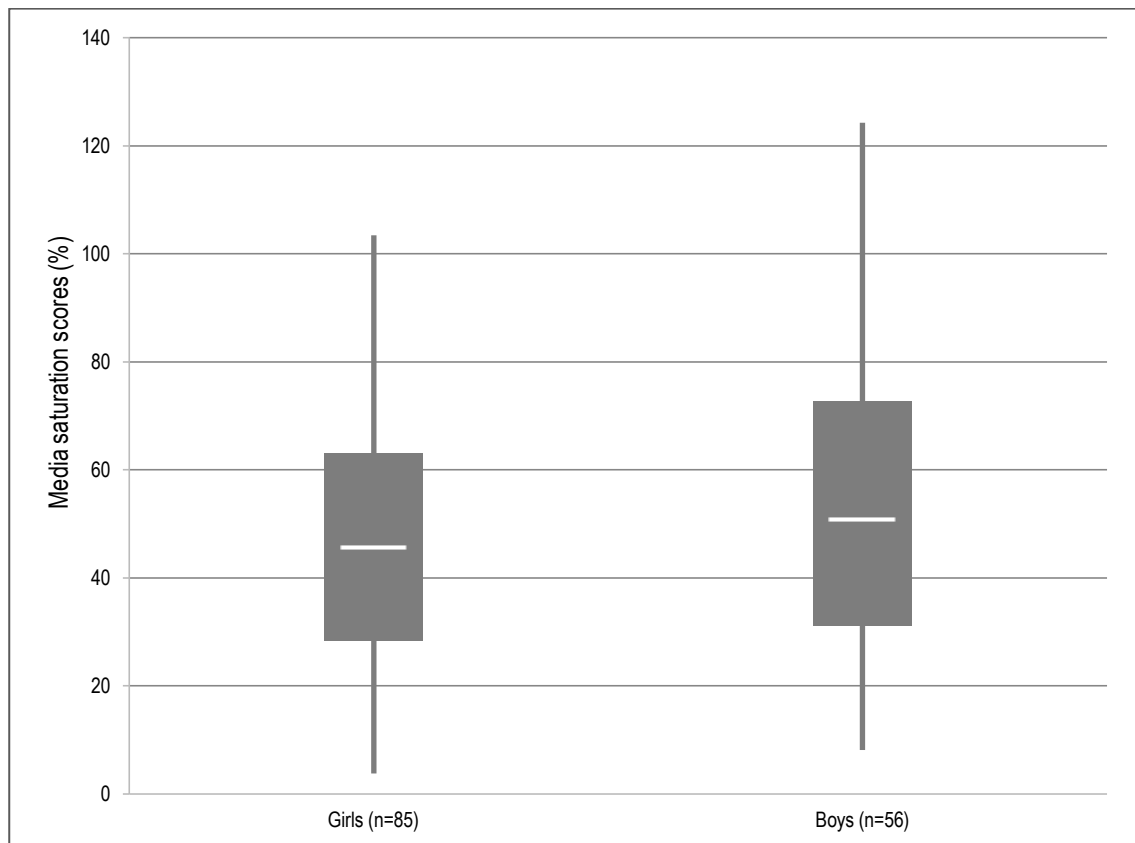
Figure 4.8. Summary of descriptive statistics for media saturation scores by sex.

> **Media Assertion IV: Some participating students are exposed to multiple media at one time.**

Some regional variations in media use by sex were observed, though the numbers were too small for statistical tests. The New South Wales (NSW) sample was the most anomalous, with girls there using more media, including Internet, than the boys, opposite to the significant trends shown in Table 4.2. The difference in average media use was 1 hr 7 min per day (girls = 5 hr 16 min/day; boys = 4 hr 9 min/day), making this sample a complete reversal compared with students overall. New South Wales was also the only sample in which girls used more comics but fewer magazines than did the boys.

Age (year group).

Older students may use more media as they become more aware of it. It is also possible that parents will permit greater access to their older children. This situation was explored by sorting the individual media saturation scores from least to most for the members of each year group, overlaying the three samples in Figure 4.9.
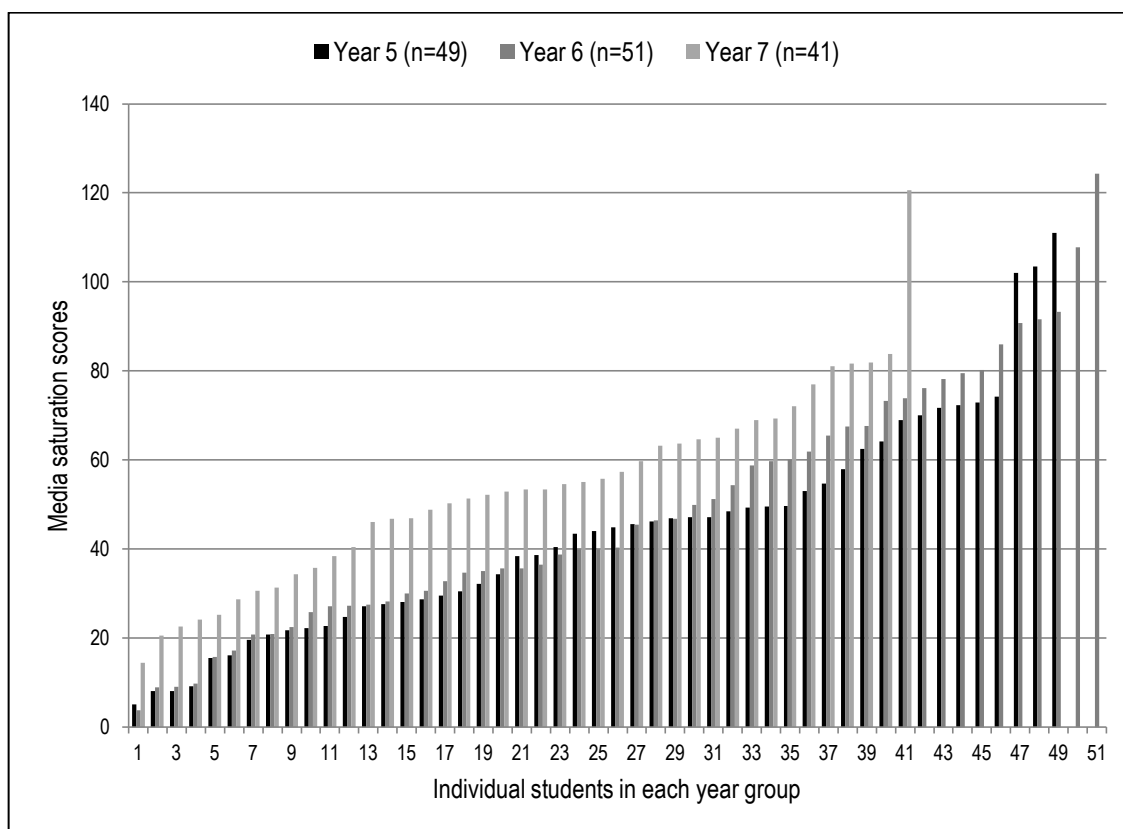
Figure 4.9. Media saturation scores charted from lowest to highest showing the wide range in each year group of participating students.

Figure 4.9 shows that each year group has a full range of media saturation scores from very low to very high, thus any trends shown by means, although useful, are not indicative of all members of a group. However, the data in Figure 4.9 also confirm that there is a general trend for media use to increase with age, particularly observable in the results for the Year 7 students.

To elucidate which media older students are engaging with more often, Figure 4.10 presents the average annual score (hr/year) data for each type of media showing age (year group) differences. Figure 4.10 shows the general trend seen in Figure 4.9 occurs for television viewing and radio, and the prevalence of usage of these, particularly television, probably drives the appearance of the general trend seen in Figure 4.9. Figure 4.10 indicates that the usage of other media follows different age trends.
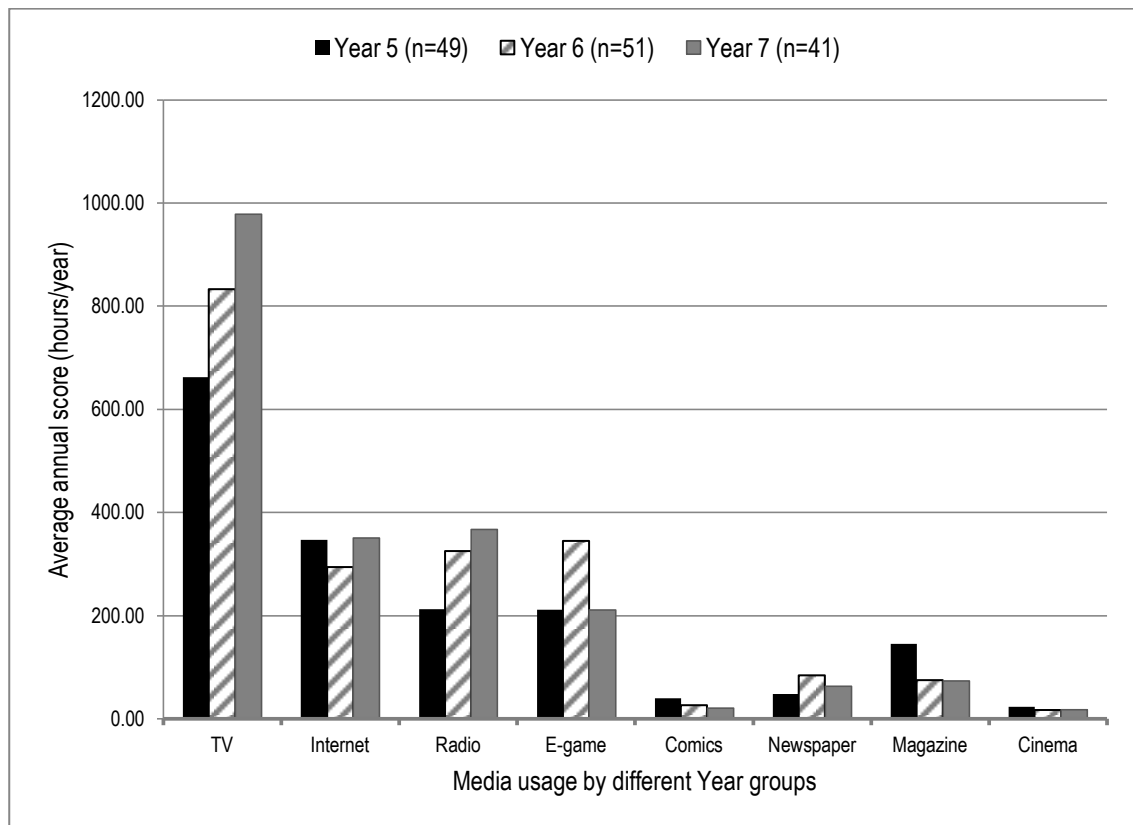
Figure 4.10. Different media usage by age (Year 5 = 49, Year 6 = 51, and Year 7 = 41).

As explained in Chapter 3, the data were square root transformed and subjected to ANOVAs to search for significant differences, which were ascribed to particular year groups by *t* tests. Table 4.3 indicates significant differences at *p* < .05.

Table 4.3

Significant differences in media usage by age (Year 5 = 49, Year 6 = 51, Year 7 = 41)

Significant difference	*M*		*SD*		*p* values	Cohen's *d*
Year 7 students watch more TV than Year 5s	Year 7	977.98	Year 7	471.45	.002	.71
	Year 5	622.45	Year 5	520.53		
Year 7 students listen to more radio than Year 5s	Year 7	366.80	Year 7	283.03	.004	.57
	Year 5	212.20	Year 5	258.41		
Year 6 students play more E-games than Year 5s	Year 6	344.33	Year 6	393.46	.033	.37
	Year 5	210.92	Year 5	321.07		
Year 6 students play more E-games than Year 7s	Year 6	344.33	Year 6	393.46	.030	.39
	Year 7	210.95	Year 7	275.52		
Year 6 students read more newspapers than Year 5s	Year 6	84.06	Year 6	119.87	.040	.35
	Year 5	48.35	Year 5	78.40		

Collectively, Figures 4.9, 4.10 and Table 4.3 show trends in media use associated with age expressed as Year group. Only TV and radio show a clear trend of increasing media use with increasing age, and these trends are both significant and substantial as shown by p and Cohen's d values. Participating Year 6 students (i.e. 11 year olds) appear to be very fond of E-games, playing significantly more than either Year 5 or Year 7 students; Cohen's d indicating these effects are not trivial ($>.2$). The Year 6 students read significantly more newspapers, but their lesser use of the Internet did not reach significance. Decreased magazine use (Year 5 to Year 6, and Year 5 to Year 7), both had p values of .06, and Cohen's d values of .3. These values suggest some effect is occurring, if not statistically significant with this sample size.

Media Assertion V: Access to television significantly increased with age in the sample of participating students.

Media Assertion VI: Participating Year 6 students read significantly more newspapers than did other students.

Socioeconomic status (SES).

The findings for this factor are clouded by disparate sample sizes. In small schools in small towns, fewer potential participants were available. The students' unfamiliarity with the research process, and indeed, with strangers visiting their school, appeared to result in proportionately fewer volunteering to participate. In the small South Australian town, I found that the strategy of simply sending the information sheets home did not work; no participant forms had been returned by the set date. The school's principal suggested I attend the school to meet the students. Aware of the benefits to the students of experiencing the research process first hand, she hoped that having met me, they would be more receptive to participating in the research. In the classroom, she suggested that the students interview me, which they did with characteristic bluntness and much laughter. They also asked some thoughtful questions about the research, especially how much I would have to write, who would read it, and what effect their participation would have. That encounter on a Friday afternoon resulted in eight signed forms arriving at the school on Monday morning, and so the research process went ahead. Nonetheless, this still constituted a very small sample.

Chapter 3 explained that the intention was therefore to pool data from schools in small towns in two states to comprise Sample 3. Statistically similar on the My School

website when selected, with ICSEA scores (indicating SES) only 21 points apart; later, data for the sampling year showed the schools to now be 118 ICSEA points apart (*1SD = 100* ICSEA points), and no longer statistically similar. Thus, the data for these two towns were analysed for evidence of similarity and difference, to assess whether pooling their data was appropriate to tell a consistent regional story.

Firstly, the average annual scores were considered for all eight media types combined. In order of highest to lowest SES, average annual scores were 1896 for Sample 1 urban Qld (*n* = 79), 1943 for Sample 2 mid-sized town SA (*n* = 43), 1740 for Sample 3 small town NSW (*n* = 11) and 2174 for Sample 4 small town SA (*n* = 8). The disparate sample sizes meant that no statistical tests were appropriate; however, a marked difference between the two small towns whose data I intended to pool was apparent. The NSW score was the lowest of all and the SA score was the highest of all. The average annual score data indicate a possible general trend of increasing media usage with decreasing SES, with the exception of Sample 3, the NSW town. This anomaly was further analysed by considering how the participating students in the two small towns in NSW and SA compared in terms of their average use of individual media, shown in the relative proportion graph, Figure 4.11.
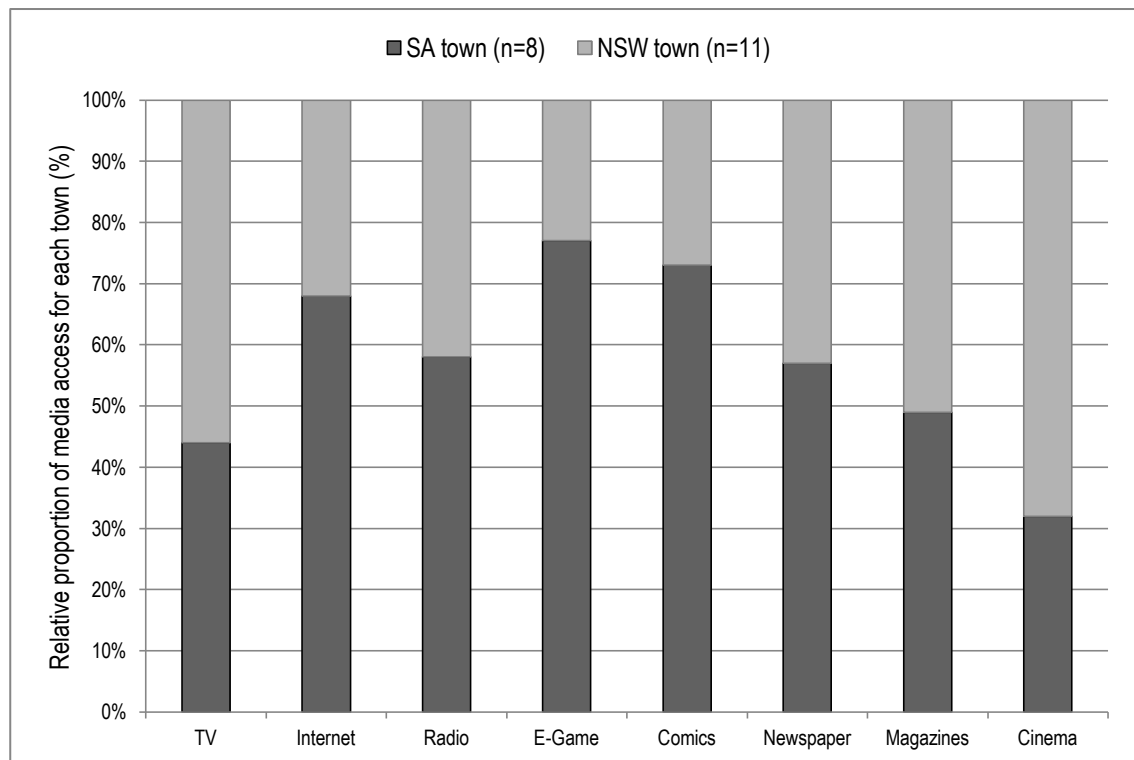
Figure 4.11. Relative proportion of the use of each media type for each town.

Figure 4.11 shows divergence from the expected 50:50 result for all media, with magazines the closest at five percent difference, and E-games the most divergent. Different distances to the nearest cinema, being 402 km for the South Australian town but only 160 km for the New South Wales town, explain divergent cinema scores. As noted previously, the NSW sample was also anomalous in its media exposure trends for sex. These data indicate that pooling these two small data sets is contraindicated, at least in terms of their media use. Henceforth, the remote New South Wales sample is Sample 3 and the remote South Australian sample is Sample 4.

> **Media Assertion VII: Participants' media usage generally increased as SES decreased (with the exception of anomalous remote sample from NSW).**

Whole sample versus interviewees.

I could only collect complete data, including genetics knowledge and perceived sources of information, for the interviewees. Therefore, it was important to establish how similar the interviewees were to the whole sample of participants. Figure 4.12 presents the average annual scores for each type of mass media for the whole sample of 141 students versus the subset of 62 interviewees. Two-sample one-tailed heteroscedastic *t* tests at the .05 level of significance showed that there were no significant differences between these two data sets; therefore, the interviewees are representative of the whole sample.
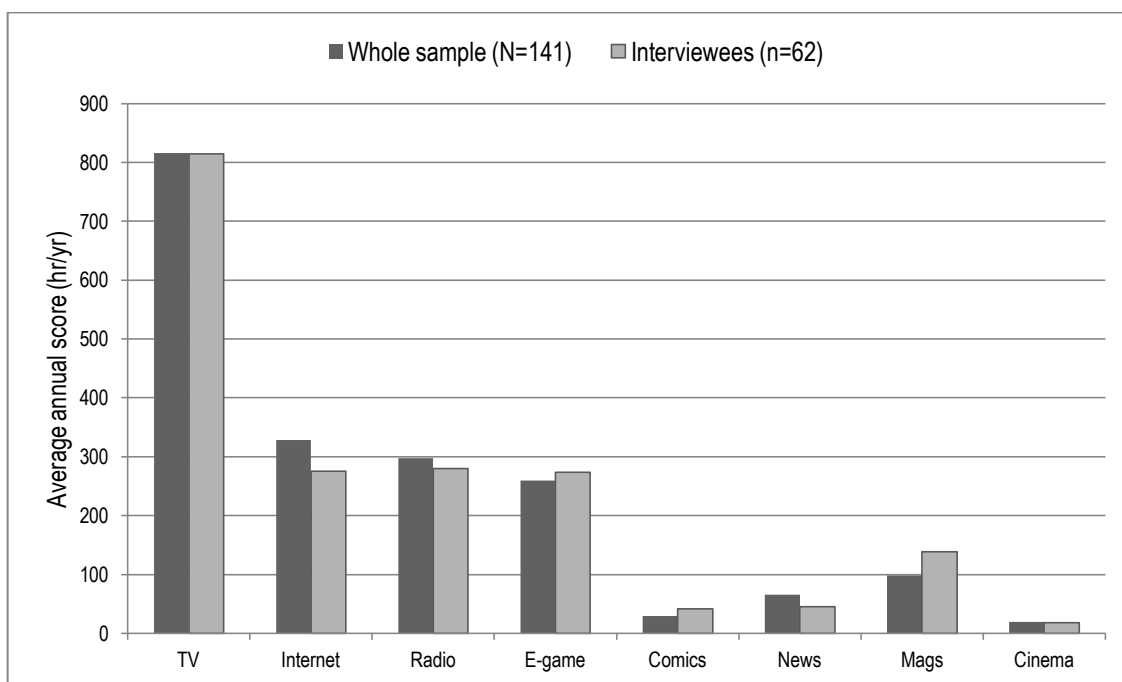
Figure 4.12. Media use by whole sample (*N* = 141) and interviewees subset (*n* = 62).

1b) What specific concepts about genetics are found in the media to which these primary students are regularly exposed?

This section focuses on the specific media with which the interviewed students reported interacting, to ascertain the genetics information embedded in these examples to compare with the students' understandings of genetics. Two questions on the media questionnaire addressed specific media examples, one that asked students to nominate favourites, addressed here, and another that asked them directly about *10 TV shows of interest*, addressed in Chapter 5.

Firstly, each student could nominate up to three personal favourites for each type of media. For the 62 interviewees, a maximum of 186 mentions (votes) were possible for each media type. Table 4.4 shows that TV polled the highest, with only three students not nominating any favourite TV shows, some naming only one or two. Table 4.4 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.

Table 4.4

Number of media nominated and top three favourites of the 62 interviewees

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 (2 types of answers)	Nintendo DS (28) Mixed games (43)	Wii (23) Sport (26)	Playstation (21) 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)

Table 4.4 shows that favourites were not universal; all media indicated diversity of students' choices. The genetics content of these favourites will be discussed for each media type in sequence as presented in Table 4.4. Students in all regions interacted mostly with their *local* radio stations and newspapers. As these media are not directly comparable, radio and newspapers are discussed at the end of this section.

Media Assertion VIII: Participants interacted with a wide variety of each type of mass media; favourites were not universal.

Television.

Television is the medium offering greatest exposure to genetics concepts, with DNA and genes embedded in many TV shows, news reports, and advertising. Of the students' top three favourite TV shows reported in Table 4.4, *The Simpsons*[1] was found to have the most genetics content. *DNA* has been referred to at least 13 times, such as in the episode *Who Shot Mr Burns Part II*[2], in which Marge claims she shares everything with Homer, including his DNA (clearly scientifically inaccurate, as she is his wife, not a biological relation). DNA features in several other episodes such as *Snowball II, Mona Simpson,* and in at least four of the character Troy McClure's films, including *Someone's in the kitchen with DNA*.

The Simpsons has referred to *genetics* at least 11 times in, including Bart writing on the chalkboard, "Genetics is not an excuse[3]," and in episodes such as *The Homer They Fall,* and *Dr Simpson.* The word *gene* has been used at least eight times in episodes such as *Abbie*, *Treehouse of Horror Parts I* and *II,* and most notably in *Lisa The Simpson*[4]. In this episode, the smart character, Lisa, is very concerned that she has inherited the "Simpson gene[5]," which makes her father Homer dumb. Meeting all the other male relatives in the Simpson family only serves to reinforce her fate. Eventually she finds out that female Simpsons are successful, and that the Simpson gene, contributing to baldness and laziness, is on the Y chromosome, so is expressed only by males, although apparently to varying degrees. She and her little sister Maggie are safe, as they only have X chromosomes. This explanation is partly consistent with biological sex determination, with the Y chromosome being associated with boys, although there is no such gene on the human Y chromosome. *The Simpsons* wiki website[5] adds a complex "biological" interpretation of the episode, inconsistent with Y-limited genes, though it does introduce terms such as *allele* and *hemizygous* and sounds convincing to those lacking specialised knowledge.

Such is the popularity of *The Simpsons*, that scientists who discovered that deleting a particular gene in mice made them smarter at solving mazes and other tasks, dubbed it "the Homer Simpson gene" (reported widely, including in *Medical Daily, 18/9/2010*). The RGS14 gene is expressed in the hippocampus, the part of the brain involved in memory formation, and although the gene is also in humans, its function is not yet fully understood. Disabling the gene appears to have enhanced the response of the mice to visual cues. However, there is no evidence it is on the Y chromosome or contributes to baldness and laziness as in the TV show.

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The second most popular TV show mentioned by interviewed students was *Home and Away*[6]. Of the 5,365 episodes aired at the time of writing, synopses are available for approximately 3,200 of them. In those, DNA was raised only five times, being tests for paternity (2), and crimes (3). These references are more in passing to justify a storyline, rather than the focus of the show. The earliest reference occurred in Season 14 (2001), aired when the participant students were infants, however they may have seen two such references in Season 20 (aired 2007) and the others in Seasons 21 and 24. The main messages received from these references are that DNA is used to decide paternity and to investigate crime.

It was impossible to know which shows students had viewed on their third favourite, the Disney channel, so I could not ascertain the genetics content of this selection. Of the other shows that students nominated as favourites, *Bones, NCIS, NCIS: Los Angeles, The Mentalist, Law & Order, Cold Case* and *Can We Help?* are included in the *10 TV shows of interest* in this study, and subject to detailed analysis for genetics content in Chapter 5.

Interviewed students also nominated *George Gently, The Bill,* and *Criminal Minds* as favourite crime shows. DNA evidence was first used in UK courts in 1986 and in the USA in 1987. *George Gently*[7] is set in the 1960s, so never refers to DNA. *The Bill*[8] commenced in 1984, so there was no reference to DNA in the early seasons. The focus of the show was always standard police work rather than forensics. In the seasons that these students may have conceivably watched, DNA was mentioned in the synopses of only two episodes. In one, a victim of possible rape refuses to allow a DNA sample to be taken, and in the other, DNA is used to try to track down the murderer of a police constable. *Criminal Minds*[9] focuses on psychological profiling of criminals, and tracking suspects by searching public records. Fingerprints are used, but DNA is referenced only nine times in the synopses of 142 episodes, and is not the focus of the show. These references are accurate scientifically, though often a source of banter between characters. In one episode, officers find too much DNA, and the team laments that elimination is not possible with 100 DNA samples mixed: a real scientific issue.

Of all the other shows mentioned by students as favourites, three others contained references to genetics topics. In over 6,000 shows, *Neighbours*[10] referred to it 12 times. In 2006, three episodes concerned a DNA paternity test. In 2007, two episodes concerned a DNA test to ascertain family relationships, specifically a grandfather, and three concerned a DNA paternity test. In 2009, four episodes covered more DNA tests

to ascertain familial relationships, specifically half-siblings, with the first "standard DNA test" proving inconclusive, inciting one of the characters to steal money to buy an $8,000 DNA test, which "proves" the relationship. The references have reasonable scientific accuracy, though generally supporting DNA as being ultra-reliable evidence. The key message from these episodes is that DNA is used to determine family relationships accurately.

Genetics topics may be raised unexpectedly. For example, despite the main characters being physicists, the TV show *Big Bang Theory*[11]'s lead character, a know-it-all named Sheldon, often lectures another lead character Leonard, about genes and DNA. In the pilot episode, Sheldon delivers his lecture in the context of them donating sperm to a "high-IQ sperm bank." In another episode, Sheldon performs unseen DNA manipulation to create a luminescent goldfish to use as a nightlight. In various episodes, Sheldon also hoped to a) clone Leonard Nimoy (the actor who played Spock on *Star Trek*) from DNA on a signed napkin; b) recombine DNA to turn the dead family cat into a griffin; and c) create a DNA model for a silicon-based life form. Sheldon worries about the fate of his line of DNA because his fraternal twin sister, who is far more successful socially than he is, shares his DNA. At least five episodes have mentioned genetics, mostly in the context of Sheldon's superiority, though in one episode he suggests buying a genetically altered calico cat whose fur is hypoallergenic. Most references are technically correct although exaggerated, rapidly and superciliously delivered to create humour. It does not focus on DNA tests for crime, and its references to recombinant DNA seem rare for TV shows.

Finally, the animated show *Futurama*[12] refers to DNA, particularly in two episodes in 2008, in the context of a purported species capable of preserving the DNA of endangered species, including that of humanity. This episode highlights a different aspect of DNA from the other TV shows, its presence in all organisms, and its loss when a species becomes extinct. Although the Encyclopod species and its capacity to preserve DNA is a creation of the show, the underlying concepts concerning the importance of genetic diversity is scientifically sound. These examples serve to highlight the ubiquity of mentions of genetics topics in a variety of television shows.

> **Media Assertion IX: Mentions of DNA, genes, and genetics were found to occur in many of the participants' favourite television shows (not just in crime shows).**

Television news.

The questionnaire did not specifically ask students whether they watched news broadcasts on TV, although two listed it as a favourite, an unexpected finding. It is likely that they are exposed to them on some occasions by the frequency with which TV news or news headlines is promulgated, appearing several times from late afternoon through the evening, and again first thing in the morning on some channels. Television news broadcasts, sampled as described in Chapter 3, showed that genetics concepts are displayed in proportions and contexts matching those found in newspapers, discussed at length later in this section.

Television advertising.

Genetics topics also occur in advertising. Tracking down all examples is impossible, but over the three-year period of this research, five examples stood out. Two aimed at women are from rival cosmetics companies; Revlon[13] advertised that their make-up product has "age-defying DNA Advantage™" and Lancôme[14] that "Youth is in your genes. Reactivate it. Discover the skin you were born to have" with their Génifique Youth Activator product. Delving beyond the advertisements to the company websites, Revlon explains how UV rays from sunlight can damage the skin, and their age-defying advantage turns out to be the inclusion of a sunscreen to protect your skin's DNA. This is useful, but not an exclusive feature of their product. Lancôme's website is less informative, with vague promises about "boosting gene activity" and "activate youth proteins." This appears to be a case of using the mystique of genes to market an expensive product. These advertisements appeared on television and often as prominent full-page advertisements in the first few pages of many women's magazines.

The first example aimed more at men was a hardware company, Mitre 10, which proclaimed "DIY. It's in our DNA." This was a symbolic use of the word DNA, implying that Do-It-Yourself (DIY) is central to their core business. The TV advertisement[15] for this campaign, made for New Zealand, contained "Kiwi versus Aussie jibes" from children in a sandpit. This advertisement was a huge hit on YouTube, the students' most popular website, so it is likely some will have seen it. Some Australian Mitre 10 stores also adopted the slogan in their advertising.

The second male-targeted example was the work clothing company, King Gee[16], which conducted a long-running campaign on television and billboards that asked, "Have you got the King Gene?" The TV ad featured heavily through key sporting events such as

the Commonwealth Games and the Bathurst 1000 V8 Supercar race. The advertisement indicated that successful tradesmen have "got it," that attractive girls think they're "hot," that you can be born with the King Gene that King Gee have identified, shown by a pull-down screen featuring the DNA double helix, if you've got it you are destined for great things, whereas a clumsy worker who drops something "hasn't got it." Figure 4.13 shows a version of this advertisement captured on a billboard in New South Wales.

Figure 4.13. King Gene billboard (photo taken by author, Lithgow, NSW, 19/4/2011).

At the time, their website had an option to upload a picture of yourself and receive a picture back of you as a King Gene baby along with a birth certificate that states your "King Gene number as evidenced by a DNA test," signed by Dr L. Gene. Their website[16] still features the DNA double helix as a backdrop for their title. At least this campaign links the concepts of gene and DNA together, though obviously there is no king gene to make you an efficient and attractive worker.

Finally, aimed at both men and women was a short advertisement by American Express[17], stating that DNA is wonderful stuff, it is what makes someone individual, and that their company offers personalised service like no other. The visuals involved molecules forming into the DNA double helix and then forming the names "laura," "daniel," and "julia" with the helix. These advertisements collectively indicate that advertisers use DNA and genes to promote their messages with only minimal attention paid to the biological nature of these molecules, and much more concern for the symbolic and mystical frames of reference that these molecules now embody.

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> **Media Assertion X: In advertisements, DNA and genes were referred to in symbolic rather than scientific ways.**

Websites.

Participants mentioned games generally or specifically 37 times, apparently being their key motivation for using the Internet. The websites in Table 4.4 were the top three individual sites nominated by the students. By contrast, seeking information (other than those who nominated Google for unknown purposes) occurred 12 times, and using the Internet to keep up with specific interests such as horses or cooking was referred to only six times. Chat sites and online shopping received five votes each, and using email mentioned only four times. It is impossible to ascertain whether students accessed material containing genetics references on sites such as YouTube (the Mitre 10 advertisement being popular there as mentioned), or Google. Accessing specific websites mentioned located no genetics content.

E-games.

For the E-games question, some students simply nominated their choice of console and others just wrote *games* instead of listing specific games as requested. Therefore, the numbers in Table 4.4 indicate the relative popularity of each of the top three console types, and of the types of E-games mentioned. The console types are not linked to the game types in each box. It was possible to ascertain that at least 28% of the respondents, mostly in the higher SES regions, have access to two or more different E-game consoles. Accessing specific E-games mentioned uncovered very little genetics content (only in *Pokemon*[18] mentioned by two students).

Comics.

Of the 18 comics nominated by students as favourites, half relate to specific characters such as *The Simpsons, Phantom, Spiderman,* and *Archie.* Of these, only *The Simpsons* is known to have featured genetics content, particularly in issues related to the TV episode *Lisa The Simpson*[4], which refers to the "Simpson gene[5]." This is the only detailed reference to genetics according to published synopses, appearing in four issues, though given that *The Simpsons* television show refers to DNA and genes moderately often, it is likely that these topics have been raised in passing in other issues. Most of the remaining comics relate to animal characters such as *Garfield* and *Donald Duck*, are satirical such as *Mad*, or are referred to only as *newspaper comics*

which are likely to be a mixture. Sampling of these comics yielded minimal references to genetics concepts.

Magazines.

Table 4.5 provides a breakdown of the nature of the 34 magazines mentioned by the interviewed students.

Table 4.5

Nature and typical examples of the 34 magazines that students reported reading

Nature of magazine	Number of magazines	Typical examples
General children's	6	*K-Zone, D-Mag*
For women	5	*Take 5, Women's Weekly*
For either girls or boys	5	*Girlfriend, Dolly, Krash*
About sport	4	Rugby, cricket (specific titles not given)
About cars/motorcycles	3	*Top Gear, Two Wheels*
For teens	3	*Hannah Montana, High School Musical*
About animals	3	*Horsewyse, Horse Deals*
Other	3	*Mad, Better Homes and Gardens*
TV/movies	2	*TV Week, Reality*
TOTAL	34	

Sampling showed that the genetics content of magazines is variable. Genetics content was not found in any of the general children's magazines samples. A search of *Girlfriend*[19] showed DNA referred to twice, in articles about why boys and girls are so different, a literal use of the term, and putting the "muse" in musician, a symbolic use of the term. None was found in *Dolly, Total Girl,* or *Krash*. It was difficult to follow up sports magazines, as students did not name particular titles. None was found in the car and motorcycle magazines sampled, though past advertisements mentioning DNA and cars have been recorded, for example the replica Ferrari known as the DNA 351XTY[20]. I found no genetics content in the teen magazines mentioned by the students. Magazines concerning animals may sometimes mention DNA in terms of bloodstock, though not in the samples examined. Magazines concerning TV and movies may occasionally refer to DNA, such as two short articles found about two different celebrities (Jude Law and Keanu Reeves) concerning DNA paternity testing, and an expanded advertisement for a crime show. Samples of *Mad* did not contain any genetics content.

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The most likely sources of references to DNA are the women's magazines. The *Women's Weekly* samples yielded three articles, one about ageing that referred to telomeres[21], the DNA sequences on the ends of chromosomes, another stating that the cause of migraines could be in your genes[22], and a third claiming that Elizabeth Taylor's eyelashes[23] were due to a genetic mutation. The first two articles were reasonably scientifically accurate, arising from scientific reports and newspaper articles. The third was decidedly more dubious. *Woman's Day* yielded two linked articles referring to DNA tests for celebrity paternity (as in the TV magazines). These articles refer to, but do not explain DNA tests. Another article[24] referred to the famous missing child case of Maddie McCann in Portugal. This article begins by implying there is "no doubt" about the DNA results proving the child was moved in the McCann's car, but goes on to explain that these were "low copy DNA tests" considered unreliable in the UK, but definitive by the Portuguese press. This latter part is accurate, although the article does not explain "low copy."

These major women's magazines also contained advertisements featuring genes and DNA such as "Génifique," described earlier[14]. These ads are often full-page and prominently placed, but the scientific accuracy of these advertisements is poor.

Magazines such as *Take 5* and *That's Life* focus on stories sent in by everyday people. Topics include stories about family relationships, particularly adoption, such as a girl[25] with breast cancer who traced her biological mother to find out "the secrets in her DNA." Explanation of DNA tests in these stories is rudimentary at best. An article[26] on "dentists to the dead" who use teeth and dental records to identify people explained this reduced the need for expensive DNA tests. An article[27] on a real forensic scientist was particularly useful in identifying some of the myths inculcated on crime shows. These myths include one scientist identifying lots of different types of evidence (they specialise), scientists questioning and arresting suspects (they do not), instant testing for blood or gunshot residue (which can take weeks), and revealing bodily fluids under fluorescent lights (does not work). Also located were 35 articles referring to the words *genes* or *genetics*, nearly all about genetic conditions, diseases, pregnancy and inheritance. Four of these articles further referred to *mutation*, whereas only two referred to *chromosomes*. Most were accurate, although simplistic in their explanations. Many of these stories have authorship quoted as "by x (the everyday person) as told to y (a journalist)" whose job was presumably to check and correct details prior to publication.

Better Homes and Gardens also contained two articles with genetics concepts, but no mention of the word *DNA*. An article[28] on weight loss included the words *genes* and *genetics*, and claimed that a healthy lifestyle could easily overrule genetic tendencies, yet as Lee's (2009) review article shows, the obesity research consensus over the last five years is that genes influence 60-80% of a person's weight and body size. An article[29] on individual's eco footprints suggested buying organic food as it does not contain GM organisms. The article offered no explanation of exactly how that related to your eco footprint, and did not mention the pros and cons of GM foods.

Media Assertion XI: Some magazines named as favourites by participants had genetics content, some of which was of dubious scientific accuracy.

Movies.

Only five of the 79 movies nominated as favourites by the interviewed students had genetics themes. These are *Elf*, *Pokemon Forever*, *I Am Legend*, *G Force*, and *Avatar*. Different individual students named the first three of these movies. *Elf*[30] is taken to a paediatrician for a DNA test, and in *Pokemon Forever*[18], the character Mewtwo is extra strong due to genetic enhancement by humans, and now having the DNA of the legendary Pokemon. In *I am Legend*[31], mention is made of a genetically enhanced virus. *G Force*[32] received three votes. This movie is about a group of animal secret agents who believe they are genetically enhanced, but who find out that they are not. At the time of data collection from Sample 1, *Avatar*[33] had not been released, yet it still received eight votes from Samples 2, 3, and 4, making it the second most popular movie. *Avatar* refers to the genetically engineered hybrids between humans and Na'vi, the natives of the world Pandora. Genetically matched humans operate the hybrids mentally. This idea is established early in the film, with the main themes of jungle story, star-crossed love story, imperialism, and deep ecology taking over. The key genetics message students are likely to ascertain from these movies concerns genetic enhancement, the concept of producing improved species, particularly humans. Genetic enhancement has been ongoing for thousands of years in selective breeding programs for plants and animals, though today, the term usually refers to active forms of genetic engineering such as recombinant DNA or gene insertions. Genetic enhancement in real life raises many ethical as well as technical issues, rarely explored in cinematic portrayals of the process. However, these movies do not focus specifically on the relationship between genes and DNA, nor how DNA works.

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Radio.

Of 79 total references to radio, 63 were of local stations. The only show mentioned by students from more than one region was "Hamish and Andy." When monitored, no mentions of genetics were made in their show. Samples of all local radio station showed the programming was primarily music, with some chitchat, competitions, news, and frequent advertisements. More serious topics were raised rarely, and then not for extended periods. The only reference to genetics was one news report (in Sample 1's region), referring to a DNA test proving that undersized (illegal) mud crabs from Queensland had been sent to New South Wales, also reported in the local newspapers[34]. Consequently, although students often listen to radio, they do not listen for long, making their likely exposure to genetics concepts minimal.

Newspapers.

Participants mentioned newspapers 54 times; local newspapers (35), state or national newspapers (8), weekend newspapers (7) and rural-focused (4). It was unclear whether the weekend newspapers were local or state based. Consequently, local newspapers were sampled twice, when the interviews were conducted, and then later by Internet to collect comparative samples in the same month. Differences were found in the incidence of newspaper reports on genetics topics, and in the nature of these reports in terms of different topics.

In all, 102 newspaper articles mentioned genetics topics, ranging in size from a snippet of $28cm^2$, to feature articles occupying $1,998cm^2$, which is equivalent to over 4xA4 pages. Most (59%) articles included pictures, often the same stock photos, whether or not they accurately encapsulated the content. The three most common images were the DNA helix, a close-up of the lenses of an ordinary light microscope, and gloved hands holding a small vial and a micropipette. The least appropriate of these is the light microscope, as DNA and genes cannot be seen under such an instrument. Crime reports often added a stock photo of the bars of a jail cell door.

> **Media Assertion XII: Images commonly associated with genetics content in the participants' local newspapers were light microscopes, DNA helix, and gloved hands holding vials and micropipettes.**

A word referring to an aspect of genetics, such as *DNA, gene, genome, genetic, genetically,* or *chromosome*, was in the headline, subheading or line one in 40% of the

articles, often in a larger or bolder font than the rest of the article. In a further 17% of the articles, such a word occurred in the first two paragraphs of the article, or attached to a photo as a caption. Editors may use this prominence as an attention-grabbing technique. Another 16% of articles first mentioned the genetics aspect at the very end, possibly to catch the eye of readers skimming through, and in some cases, the connection with the body of the article was tenuous. In the remaining 27% of the articles, the genetics concept was first mentioned in the middle or main body of the article in standard font.

> **Media Assertion XIII: Genetics content was prominent in articles found in participants' local newspapers.**

Chapter 3 explained and exemplified the criteria used to assess genetics content accuracy. Accuracy was disappointing in newspaper articles; 41% simply used terminology with no explanation, and 19% were poor, with gross errors of content. Only 24% were judged fair, making a reasonable attempt to explain at least some of the terms used, and a mere 13% were judged good, with adequate and accurate explanation. The final three percent were difficult. In all, some seven percent of the articles offered only nonscientific uses (symbolic uses), mostly of DNA, one such article referred to genes. Only one of these articles attempted any explanation, and this was poor. Genetics on TV was generally more accurate than genetics in print.

> **Media Assertion XIV: 60% of participants' local newspaper articles about genetics had no or poor scientific explanation of the genetics concepts.**

Content analysis of the articles exposed distinctive patterns in the focus or theme of the articles, and the inclusion or exclusion of other words within each theme. These themes emerged throughout the analysis. Table 4.6 shows the 11 themes that emerged from the 102 newspaper articles found to contain genetics content, and the percentage of these articles that fitted into each theme. It also shows the percentage of these articles that focused on each aspect of genetics within each theme, and words occurring more than once in the articles for each theme.

> **Media Assertion XV: Eleven themes emerged from analysis of 102 newspaper articles referring to genetics concepts, of which disease and crime were the most prevalent.**

Table 4.6

Genetics themes and word patterns emerging from newspaper articles that mentioned genetics (N = 102)

Themes that emerged from analysis	% of *n*	Main genetics aspect mentioned	Also mentioned (most to least)
Disease – mostly specific diseases such as Alzheimer's, cancer, autism, obesity, migraine, swine flu, Rett syndrome, and early onset menopause. Six were about babies, including one about a baby genetically designed to be cancer-free.	28	Gene (16%) DNA (8%) Genetic (4%)	Specific or general disease, mutation, chromosomes, babies, inherited, telomere/telomerase, microRNA, carriers, risk, blood, variants, germline, allele, cells, nucleus, mitosis
Crime – mostly about crimes solved (e.g. 6 cold cases and an 8 year old who scratched his sister's would-be abductor to get criminal's DNA under his nails because he saw it solved crimes on *NCIS*[35])*; also five questioning DNA accuracy; two about human rights and DNA databases.	27	DNA (23%) Gene (1%) Genetic (3%)	Evidence, forensics, crime scene, cold case, database, blood, skin, junk science, other forensic methods e.g. ballistics, fingerprints
Other organisms – identifying animals; extinctions; GM crops.	13	Equally between DNA and genes	Gene pool, evolution, extinction
Nonscience – symbolic references e.g. J.K. Rowling injected "Roald Dahl's DNA" into Harry Potter[36]; that it is in the "aussie DNA"[37] to enjoy horse-racing; maintaining integrity in the "Aussie Football League's DNA[38]."	7	DNA (6%) Gene (1%)	Blood, skin, changed actor's DNA[39], genes of Christianity[40]
"**Good**" **genes** – about links between genes and youthful looks and beauty; niceness[41]; and mate selection.	6	Gene (5%) DNA (1%)	Dominant, recessive, twins, identical, fraternal
Diet, weight, fitness – linking diet[42], genes and blood groups; DNA to exercise methods; ability to taste fats in diet to weight loss/gain; metabolism and food research.	6	All gene or genetic, DNA once only	Destiny, genetic make-up, disease, GenoType diet

Themes that emerged from analysis	% of n	Main genetics aspect mentioned	Also mentioned (most to least)
Genome sequencing – mostly genomes of other organisms such as ancient birds[43], Antarctic krill[44], flea[45].	5	DNA (4%) Gene (1%)	Genome/genomic, cells, code, blueprint, ATCG/base pairs
Archaeology – new human ancestor[46]; Dutch sailors' DNA in WA Aboriginals[47]; Asians in ancient Rome[48].	3	DNA only	Mitochondrial DNA
Family relationships – one celebrity gossip[49], one claim of twins having different fathers[50].	2	DNA only	Heteropaternal superfecundation
Personal identity – about issues such as access to birth records[51] and rights of children born through donation to know their genetic background[52].	2	Genetic only	Disease
Sex/gender – femaleness of medal-winning African athlete questioned, father upset about humiliating chromosome tests[53].	1	Chromosome only	Sex, gender, humiliation

Media Assertion XVI: The presence of DNA in the nucleus of cells was rarely mentioned in the sampled newspaper articles, appearing only in two articles about disease.

Media Assertion XVII: No newspaper articles specifically explained the biological function of DNA/genes, which is to produce proteins for growth and regulation.

Media Assertion XVIII: Chromosomes were rarely mentioned in the sampled newspaper articles, appearing in nine articles about disease, and in an article about sex/gender.

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Table 4.6 shows that *genes* are linked to *disease*, with the word *genes* occurring 78 times (nearly 3 per article). In articles in the disease theme, the word *disease*, or specific diseases such as cancer and Alzheimer's, are mentioned 362 times (13 per article). No other word occurs at a similar rate, not even *genome* in the genome-sequencing articles (6 per article). Some of the articles about genetic diseases also referred to DNA, but only eight percent were more about DNA than about genes or genetics. The word *mutation* occurred 52 times, but in only a few articles (6-7 times per article), and rarely explained. One 2xA4 page article about Fragile X[54] included *premutation* 15 times, and *mutation* four times, but did not explain the difference between the terms. The headline of the Fragile X article referred to autism genes, yet barely mentioned autism thereafter, and referred to *carriers* 18 times, without explaining the term. Genes are also commonly mentioned in articles about "good" genes, such as genes for "niceness" linked to female genes as apparently revealed by twin studies[41] and in articles about diet, weight, and fitness.

Crime articles were far more likely to refer to DNA than genes, with *DNA* appearing an average of four times per article. Other crime-related words such as *evidence*, *forensics*, *cold case*, *crime scene*, *CSI*, and *database* only occurred in crime stories in conjunction with DNA, on average, between once and twice per article. The one exception relating genes to crimes was a review of a book postulating a genetic predisposition to commit crimes[55], due to brain disorders, diseases, or through the action of the Y chromosome (that is, being male). In the 1960s, poorly structured studies linked criminal behaviour to being XYY. Although discredited in the 1980s, this notion has lingered in high school textbooks and crime show plots. Explanations about DNA in crime articles were absent (11), poor (6), or fair (8); none was good.

Table 4.6 indicates that journalists seem to have adopted different suites of words for each theme and aspect of genetics to transmit their intended messages. Most students (85%) reported spending up to an hour each time they looked at a newspaper, and less than 20% said they never look at one. Even from just noticing headlines or scanning articles, the impression gained is that DNA links with crime, and genes with disease. Thus, newspapers cannot be ignored in terms of these students' understandings of genes and DNA. As noted previously, the genetics content of television news closely paralleled that of newspaper articles, unsurprising given the concentrated ownership of both forms of media in Australia.

Media Assertion XIX: In sampled newspaper articles, different suites of words were found for each theme; *gene* was most associated with disease or health, whereas *DNA* was most associated with crime and paternity.

Media Assertion XX: Only five percent of sampled newspaper articles attempted to explain the structural relationship between genes and DNA.

Media Assertion XXI: In 102 newspaper articles about genetics, DNA was mentioned 206 times, gene was mentioned 140 times. This tendency to mention DNA more often was also noted in other forms of mass media.

The nonscience articles were more likely to mention DNA, with headlines and statements that obfuscated the scientific meaning of this term. One article on children's literature[36] claimed it is possible to see in Roald Dahl's first story "some of the DNA" that J. K. Rowling would later inject into her stories about Harry Potter. Students who are fans of Harry Potter might be attracted to this article by its headline. An actor, Adrian Grenier, in saying that the role that catapulted him to stardom had "changed his DNA in real life[39]," made perhaps the most outrageous claim. This headline grabbed attention and completely misrepresented the science of DNA. Two articles about sport also mentioned DNA, one claiming that betting on horseracing is in the "Aussie DNA"[37] and the other, that the desire for integrity is "in the DNA" of the Australian Football League[38], both dubious claims. The only article in this group to mention *genes* was in response to a potentially blasphemous entry in an art competition. An Anglican Bishop commented, "We're fair game. We don't threaten to kill someone because they insult Jesus Christ even if you find it offensive. It's not in the genes of Christianity[40]."

Some articles in the "good" genes theme could also have been included in the nonscience category because at best, they were very misleading. For example, the article that headlined "Niceness is in your genes: study"[41] explained the basis of twin studies, but made vague statements such as "adds to a growing body of research," and presented conflicting arguments with no quantitative basis with which to compare them. Only at the end of the article was a prominent scientist quoted as being cautious about interpreting the findings of the study, but this quote was followed by claims that "many geneticists" think that attributes and abilities such as a good memory and religious fervour originate in our DNA.

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Different themes were allocated different amounts of space in the newspapers. Table 4.7 shows rank ordering of the same themes explicated in Table 4.6 based on two different measures of space, the percentage that theme occupies of the total space given to genetics articles, and the average space per article on each theme.

Table 4.7

Rank order of themes as percentage of total space, and as average space per article

Theme	Rank (% of total space)	Rank (average space/article)
Disease	1	7
Crime	2	8
Nonscience	3	2
Other organisms	4	6
'Good' genes	5	3
Genome sequencing	6	5
Personal identity	7	1
Diet, weight, fitness	8	9
Sex/gender	9	4
Archaeology	10	11
Family relationships	11	10

Tables 4.6 and 4.7 collectively show that although the theme of disease has the greatest number of articles and takes up the biggest proportion of the total space, it ranks only seventh in terms of space per article, meaning there are many shorter articles. A similar situation occurs for articles about crime, whereas nonscientific articles rank fourth in number, but third in terms of total space, and second in terms of space per article, meaning the articles are longer than those focusing on disease or solving crime. The only two articles on adoption rank at the top in terms of space per article, being long, involved articles, with a lot of personal comment and some attempt to put all sides of the issue into context. This variation means that students could get quite different messages about DNA and genes, depending upon which articles catch their eye, and which themes are of most interest to them.

Besides radio, newspapers were the only type of mass media where specific content varied with locality. Local papers for the towns in Samples 2, 3, and 4 belong to the same group of newspapers, based in Sydney, New South Wales. All have access to the

same articles, but local editors can select those they consider appropriate to run in their locality. Some genetics articles were shared in exactly the same form within this newspaper group. However, the five articles that the small town in Sample 3 shared with the midsized town in Sample 2 were completely different from the five articles it shared with the small town in Sample 4. The local papers for the town in Sample 1 belong to a completely different newspaper group, based in Queensland, and no articles from this newspaper group were shared with any of the other regions.

Table 4.8 focuses attention on the local newspaper articles for the same month in the towns sampled in this study, directly comparable in both quantity and quality. The total number of genetics articles in that month is given, that total is broken down into the specific genetics aspects focused on in the articles, and into the main themes. These themes are the same as those explicated in Table 4.6.

Table 4.8

Variation in local newspaper articles between towns in the four sample areas

	Sample 1 (Qld)	Sample 2 (SA)	Sample 3 (NSW)	Sample 4 (SA)
Total genetics articles (within one month)	**10**	**6**	**29**	**13**
Breakdown of total genetics articles within 1 month into aspect of genetics focused on				
Focus on DNA	5	5	13	0
Focus on genes	5	1	8	8
Focus on genetics	0	0	8	5
Breakdown of total genetics articles within 1 month into themes				
Crime	4	0	8	1
Disease	2	0	6	0
Nonscience	1	3	5	1
Other organisms	1	2	3	3
Other mixed	2	1	7	8

Sample 1 shared no articles or even genetics news content with any other region. There were no rewrites of the same news information presented in any of the other samples. Table 4.8 also shows that, despite being only 400 km apart, local newspapers in the towns in Samples 2 and 4 varied considerably in content, genetics focus, and themes presented. They each shared more in common with the newspaper in Sample 3's

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town (in a different state) than with each other. Sample 2's newspaper lacked any articles about the two predominant themes of disease and solving crime. Most of the *other mixed* articles in Sample 4's newspaper were about "good" genes, and weight loss/diet, including two very similar articles about genes, tastebuds, fat in diet, and weight loss presented a week apart, the first more complex[56], the second simplified[57].

Table 4.8 further shows the anomalous nature of Sample 3 (NSW), with the newspaper containing more than double the number of genetics articles in one month than those in any other sampled region. On average, nearly one genetics article a day appeared in this newspaper, of which five were nonscientific. This finding further substantiates the separation of this small remote sample from Sample 4.

This section has shown that television, magazines, newspapers, and, to a lesser extent, movies, contain more genetics content than do the other four media types sampled. There is considerable variation in the scientific accuracy of genetics content, although much lacks detailed explanation. Some content uses the genetics terms DNA and gene in completely nonscientific ways. Eleven genetics themes emerged from the study of newspaper articles, with particular genetics words associated with each theme. Statistics focused on newspapers, as they constituted a fixed sample with definite boundaries, unlike the situation for television shows. Subsequent results in Chapter 5 will focus on these media types, of which television is by far the most accessed by these students.

Media Assertion XXII: Participants were most likely to view genetics concepts on television, and in magazines and newspapers.

Media Assertion III found that boys used significantly more media overall than girls, particularly E-games and the Internet. However, the finding that genetics concepts were mainly limited to television, newspapers, and magazines, prompted further examination of sex differences by calculating *Genetics-Containing Media (GCM)* scores as described in Chapter 3. Table 4.9 provides evidence that boys are exposed to significantly more genetics-containing media than are girls.

Table 4.9

Sex differences in Genetics-Containing Media (GCM) scores

Sex	Range	M	SD	Cohen's d	One-tailed t test p value $< .05$
Boys ($n = 27$)	52-2,315	1,220.89	717.36	.45	.038
Girls ($n = 35$)	149-2,315	929.48	553.13		

Research Question 2 - Students' Expressed Knowledge of Genetics

2a) What is the level of primary students' conceptual understanding in genetics?

This section examines the understandings of inheritance, genes, and DNA revealed by the 62 students interviewed. The focus here is on their accurate scientific understandings; their incomplete knowledge and misunderstandings (misconceptions) are detailed in the next section. Firstly, as an overall quantitative measure of their genetics knowledge, their interviews were scored out of 30 as described in Chapter 3. The range of the 62 scores was wide, from 6-28, with the mean being 17.1, and the standard deviation being 5.26. This divergence of knowledge is unsurprising, as genetics is not in the formal primary curriculum in any of the sample areas, so no scholastic knowledge is expected. These scores reflect informal contact with genetics ideas rather than formal learning or ability.

Sex.

The data were examined for evidence of sex differences. The five-figure statistics summary in Figure 4.14 indicates that median values are identical, although the distribution of scores differs for boys and girls. With no expectation of which sex would know more about genetics, a two sample, two-tailed homoscedastic *t* test was performed, with $p = .534$ indicating no significant difference at $p < .05$. These values indicate that sex is not a major factor influencing the amount of genetics knowledge that these primary students have gained.
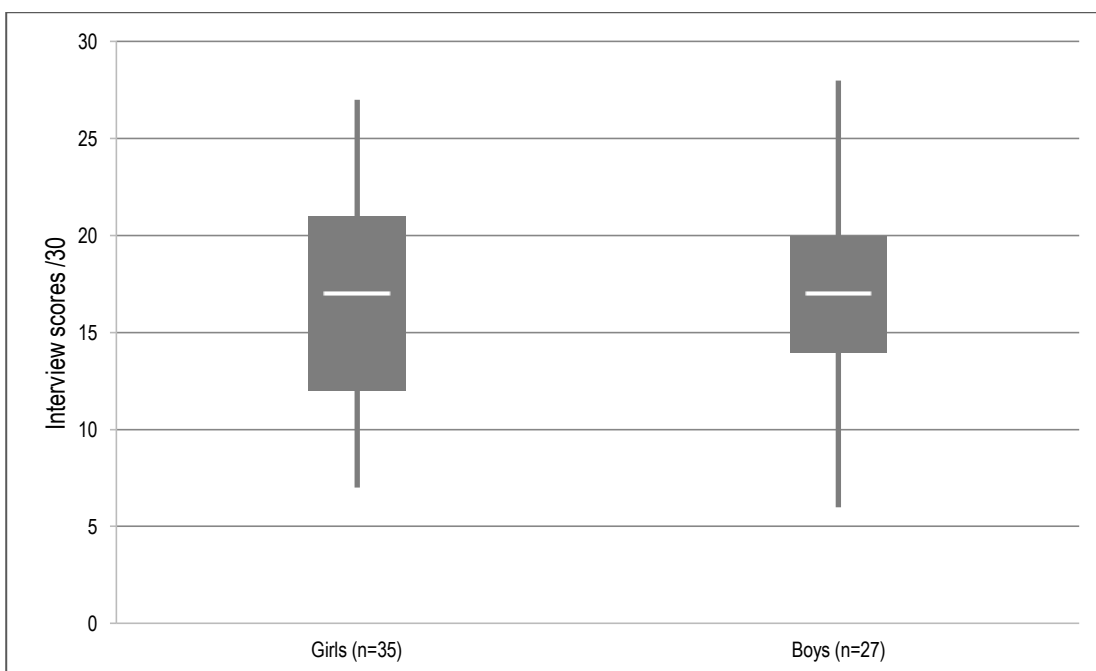
Figure 4.14. Sex differences in genetics knowledge as shown by interview scores.

Genetics Assertion 1: There was no significant difference in the genetics knowledge of participant boys and girls.

Age (year group).

The data set was analysed for the influence of age. Average interview scores were Year 5 ($n = 23$) = 13.9, $SD = 4.69$; Year 6 ($n = 21$) = 19, $SD = 5$; Year 7 ($n = 18$) = 19, $SD = 4.48$. Figure 4.15 shows five-figure summaries of these data.
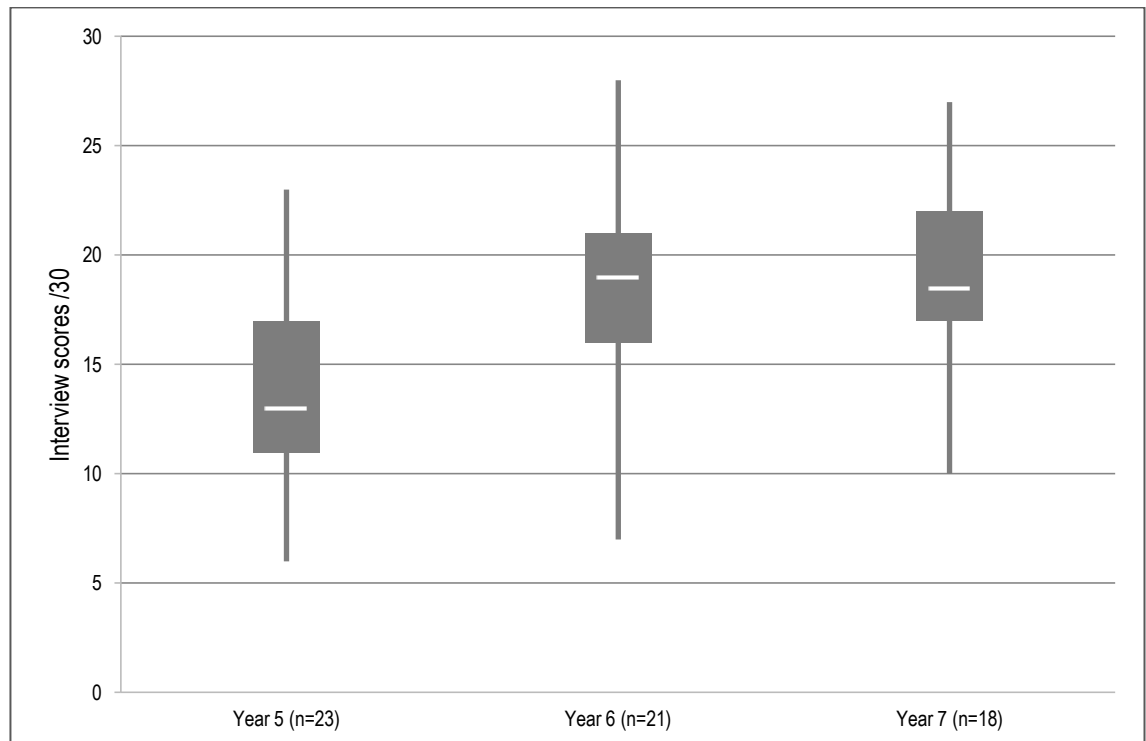
Figure 4.15. The influence of age (year group) on genetics knowledge.

Figure 4.15 visually indicates that Year 5 is different from Years 6 and 7, and the sample numbers and distributions indicate a nonparametric test to be appropriate. Thus, a Kruskal Wallis test, corrected for tied ranks, was performed on the three year group samples ($N = 62$, $d.f. = 2$, $H = 13.12$, $p = .001$). The *p* value indicates a significant difference and post hoc Mann-Whitney tests ($p = .002$) indicate the significant difference is between Year 5 and Years 6, 7. Cohen's *d* for the effect between Years 6 and 5 was 1.05 and for Years 7 and 5 it was 1.11, both large effects, but between Years 6 and 7, $d = 0$. These findings indicate a marked increase in knowledge between Year 5 and Year 6, but no further increase between Year 6 and Year 7.

Genetics Assertion 2: Knowledge about genetics increased significantly with age from Year 5 to Year 6.

Socioeconomic status.

Socioeconomic status (SES) was explored by comparing the interview scores for the four regional samples, representing declining SES (ICSEA scores) from Sample 1 to Sample 4. Figure 4.16 presents a five-figure statistics summary for the overall sample of 62 participants, and the same for each regional sample in box-and-whiskers plots.
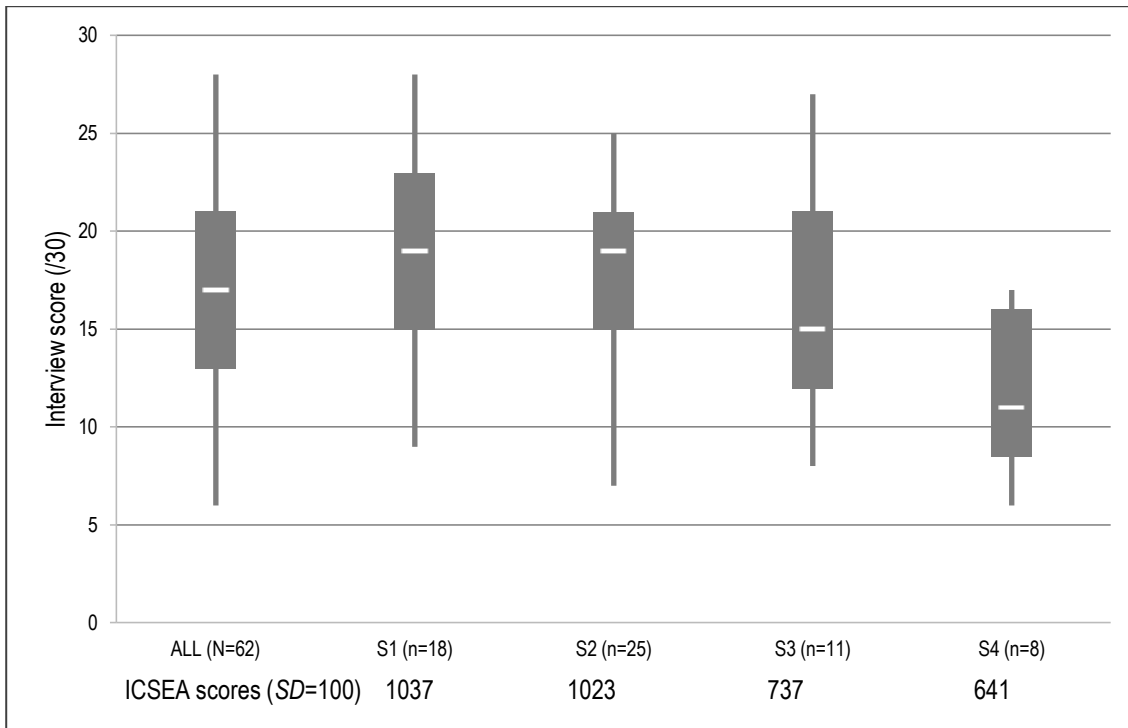
Figure 4.16. Five-figure summaries of interview scores in regional samples.

The most noticeable pattern seen in Figure 4.16 is a decline in genetics knowledge with declining SES, with participating students in Sample 4 being least knowledgeable. To see whether this finding represented a real difference, rather than an artefact of the different sample sizes, a Kruskal Wallis test was performed, corrected for tied ranks ($N = 62$, $d.f. = 3$, $H = 11.43$, $p = .009$). This is a significant result, and post hoc Mann-Whitney U tests between pairs of samples indicated that Sample 4 was significantly different from both Samples 1 and 2 (p and Cohen's d values of .003/1.54 and .004/1.38 respectively). No other pairs of samples achieved significance at an alpha level of .05. These findings confirm that knowledge about genetics declines with decreasing SES, although given the drop in SES between Samples 2 and 3 of almost 3SD, the drop in the mean interview score is less than expected.

Genetics Assertion 3: Participants' knowledge of genetics decreased with decreasing SES.

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In summary, it can be seen that the genetics knowledge gained informally by these primary students varied directly with SES, did not vary between the sexes, and increased markedly from Year 5 to Year 6. Significant findings and effect sizes presented indicate that SES was the most influential factor followed by age. Consequently, further data are presented for each subgroup from highest to lowest SES, with additional comments regarding the influence of age (year group) as appropriate.

Further examination of the students' responses determined their specific understandings, and the numbers of students holding similar levels of understanding of various concepts. These concepts reflect the sequence of questions in the interview.

Inheritance.

Interview questions about cats and kittens probed three levels of understanding about inheritance. One, whether students had any concept of inheritance, i.e. that offspring resemble parents through passing of traits. Two, if students have such a concept, whether they understand that traits pass by factors of some kind that physically move from parent to offspring. Three, if students have both ideas one and two, whether they spontaneously name the factors as DNA, genes, or both. Table 4.10 shows results for the 62 interviewed students.

Table 4.10

Students' understandings of inheritance

Understandings about inheritance	Sample 1 ($n = 18$)	Sample 2 ($n = 25$)	Sample 3 ($n = 11$)	Sample 4 ($n = 8$)	Total ($N = 62$) (%)
No concept of inheritance	1	0	0	0	1 (1.6%)
Knows only that offspring resemble parents	4	5	5	5	19 (30.6%)
Knows that factors pass from parents to offspring	0	2	1	1	4 (6.4%)
Names factors that pass from parents to offspring	**13**	**18**	**5**	**2**	**38 (61.3%)**
• Named DNA only	3	3	2	2	10 (16.1%)
• Named genes only	6	12	2	0	20 (32.3%)
• Named both DNA and genes	4	3	1	0	8 (12.9%)
• Named chromosomes	0	0	0	0	0

Table 4.10 shows that the only student who had not yet developed a concept of inheritance was a Year 5 girl from Sample 1 with the highest SES. A further 19 students (30.6%), proportionately more from the lower SES Samples 3 and 4, knew that offspring resembled their parents but could not say how this was achieved.

Only four students (6.4%) were in a transitional stage, knowing that some factors (*bits* or *cells*) were responsible for inheritance. Most students, (38 in all, or 61.3%), had a genetic theory of inheritance (Venville, Gribble, & Donovan, 2005), and were able to name DNA and/or genes as the factors responsible for transmission of traits from parents to offspring. In the higher SES samples, Samples 1 and 2, genes were more likely to be spontaneously associated with this function than was DNA. Genes and DNA were equivalently associated with this function in Sample 3, and only DNA was associated with inheritance in the lowest SES area, Sample 4. No students spontaneously mentioned chromosomes as factors involved in inheritance.

The data were examined for evidence of influence of age (year group). Although the only student with no concept of inheritance was in Year 5 and hence one of the youngest students, there was no consistent pattern found in terms of age within the remaining categories of answers. Therefore, age was not an apparent influence.

> **Genetics Assertion 4: 61% of participant students knew that DNA and/or genes are responsible for inheritance of traits by offspring from parents.**

Specific knowledge of genes and DNA.

The second part of the interview depended on the results of the first part. If students had not spontaneously said the terms *gene* or *DNA*, they were asked if they had heard of them. As none of them had spontaneously mentioned the term *chromosome,* they were all asked if they had heard of this word. If they had mentioned one term, they were asked if they had heard of the others. Students were given the opportunity to volunteer any further knowledge of these terms, and whether they thought genes or DNA would be in humans. Table 4.11 shows the results of this part of the interview.

Table 4.11

Students' specific knowledge of genes and DNA

Possible student responses to interview questions	Sample 1 (*n* = 18)	Sample 2 (*n* = 25)	Sample 3 (*n* = 11)	Sample 4 (*n* = 8)	Total (*N* = 62)
Spontaneously said DNA	7	6	3	2	18
Had heard of DNA	11	18	4	4	37
Total (%) for DNA	*18(100%)*	*24(96%)*	*7(63%)*	*6(75%)*	*55(89%)*
Spontaneously said genes	10	15	3	0	28
Had heard of genes	4	1	3	1	9
Total (%) for genes	*14(78%)*	*16(64%)*	*6(54%)*	*1(12.5%)*	*37(60%)*
Spontaneously said chromosome	0	0	0	0	0
Had heard of chromosome	4	6	2	0	12
Total (%) for chromosome	*4(22%)*	*6(24%)*	*2(18%)*	*0*	*12(19%)*
Able to offer scientific ideas	10(55%)	18(72%)	6(54%)	3(37.5%)	37(60%)
Knew humans have DNA/gene	18(100%)	25(100%)	11(100%)	6(75%)	60(97%)

Table 4.11 shows that DNA was better known than genes, with 55 students (89%) having heard of DNA, and 37 (60%) having heard of genes. Knowledge of both DNA and genes generally declined with SES, though the trend is more marked for genes. Chromosomes were the least known term in all samples, with no students offering this answer as the name of the genetic particles, and only 12 students in all (19%) claiming to have heard of them, none of whom were from Sample 4. Only three students (5%) had not heard of any of DNA, genes, or chromosomes and these were all Year 5 students, one each from Sample 2, Sample 3, and Sample 4. Otherwise, age had little influence on the findings.

In terms of being able to offer some scientific ideas about genes or DNA, Samples 1 and 3 were similar with just over half of the students being able to do so. Sample 2's students were surprisingly much more able to volunteer ideas, whereas students from Sample 4 were less knowledgeable. Most information offered concerned DNA and genes; very little additional information was volunteered regarding chromosomes. Only three students, who all scored highly on the interview, convincingly integrated what they knew about chromosomes with their knowledge of DNA and genes. Again, age did not appear to influence the findings, with students of all year groups as likely to offer ideas. The presence of genes or DNA in humans was universal knowledge other than for two students in Sample 4.

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Genetics Assertion 5: DNA was better known than genes by this sample of students.

Genetics Assertion 6: Participants rarely knew the term chromosome and did not associate it with inheritance.

Genetics Assertion 7: Knowledge that humans contain DNA and/or genes was almost universal (97% of participating students).

Only after students had volunteered their knowledge, were probing questions asked about what "it" (genes or DNA, whichever they were more familiar with) looks like, where it is located, and what it does in the body. Students were questioned about whether they thought genes and DNA were similar to, or different from, each other and why. Their answers are summarised in Table 4.12.

Table 4.12

Students' biological knowledge about genes and DNA

Interview questions	Sample 1 (*n* = 18)	Sample 2 (*n* = 25)	Sample 3 (*n* = 11)	Sample 4 (*n* = 8)	Total (*N* = 62) (%)
Location in (nearly) all cells	2 correct	3 correct	1 correct	1 correct	7 (11.3%)
	3 partly correct	5 partly correct	1 partly correct	1 partly correct	10 (16.1%)
What genes/DNA looks like	3 incorrect	0 incorrect	0 incorrect	0 incorrect	3 (4.8%)
	4 size correct	10 size correct	1 size correct	1 size correct	16 (25.8%)
	0 shape correct	4 shape correct	3 shape correct	0 shape correct	7 (11.3%)
	2 all correct	2 all correct	1 all correct	0 all correct	5 (8.1%)
What genes/DNA do in body	1 correct	0 correct	0 correct	0 correct	1 (1.6%)
	4 partly correct	5 partly correct	1 partly correct	0 partly correct	10 (16.1%)
How genes/DNA work	0 correct	0 correct	1 correct (but no mention of proteins)	0 correct	1 (1.6%)
	1 partly correct				1 (1.6%)
Are DNA/genes similar or different?	1 gave a correct reason	2 gave a correct reason	1 gave a correct reason	0 gave a correct reason	4 (6.4%)
	9 similar	16 similar	6 similar	3 similar	34 (54.8%)
	7 different	6 different	2 different	2 different	17 (27.4%)

The results in Table 4.12 show that only seven students (11.3%) could state that DNA/genes are located in all cells, or more accurately, in nearly every cell in the body, and 10 more (16%) gave the partly correct answer of *everywhere*. A further five students simply said *in the body*. No students mentioned the nucleus of cells, the most scientific answer. This question yielded 27 different locations as answers, ranging from external features such as scab pus and fingerprints, to internal organs such as brain and liver. These misconceptions are discussed in the next section of this chapter.

Genetics Assertion 8: Only 11% of participants knew that DNA/genes are located in cells; none knew the precise location of DNA in the nucleus of cells.

In most samples, about half of the students offered an answer for the question regarding what genes or DNA look like, but in all, only five (8.1%) gave answers that encapsulated both the small size and *twisty ladder* shape of DNA, or the rope-like nature of genes. More students (16 or 25.8%) correctly said these structures were microscopic than could describe the shape (7 or 11.3%), although some used hand gestures to indicate the shape. Students in Sample 4 were least knowledgeable about what DNA looks like.

Genetics Assertion 9: Only eight percent of participants knew both the small size and *twisty ladder* (helical) shape of DNA.

Genetics Assertion 10: Participants were twice as likely to know DNA was very small or microscopic as to know the shape of DNA.

Only one student (Prasai, a Year 6 boy from Sample 1) was partly correct in stating that genes and DNA contains coded information. In his words, "DNA is information. You have DNA from a mix of your parents' DNA, which tells how you should look. Identical twins have the same DNA." A further ten students gave vague answers about DNA/genes being essential for life, for growth and reproduction, or tells how to form your features. The best answer for how genes work was given by Kayley, a Year 7 girl from Sample 3, who stated that "genes work by producing messages which go to the brain and other organs to tell them how to grow and develop." No students mentioned the production of polypeptides or proteins, which is the main way in which genes are expressed.

Genetics Assertion 11: None of the participant students knew that DNA/genes work through directing the production of polypeptides or proteins.

Only four students (6.4%) clearly stated that DNA and genes are similar to each other because genes are made of DNA. They were Cory, a Year 5 boy from Sample 1; Hanja, a Year 6 girl from Sample 2, who also knew that DNA/genes were in all cells; Angela, a Year 7 girl from Sample 2; and Kayley, a Year 7 girl from Sample 3. More students knew genes and DNA are similar (total 38, 61.2%), than incorrectly thought they are different (total 17, 27.4%). Seven students offered no answer for this question, and 18 students, (equally from those saying similar and different), offered answers but no reasons, and so may have guessed. Incorrect reasons offered varied considerably from the sound of the words themselves, to known misconceptions.

Genetics Assertion 12: Only six percent of participants could describe the structural relationship between genes and DNA.

It is clear from the results in Table 4.12, that whatever the source of these students' knowledge about genes and DNA, they are not gleaning much information regarding the biological functioning of these molecules.

What DNA (or genes) can be used for outside the body.

The last part of the interview explored students' understandings of uses of DNA outside of its biological functions. Students had opportunity to volunteer their answers, but probing questions sought further knowledge that they may have. The results are summarised in Table 4.13. As recorded in field notes, students appeared more confident when answering this part of the interview than in the previous part about the biological functions of genes and DNA. Only four students could not offer any answer to this question after prompting from the interviewer. They were Alkira and Coreen, two Year 5 girls from Sample 3, and Coorain and Lamilla, a Year 5 boy, and a Year 6 girl from Sample 4.

Genetics Assertion 13: Many more participants (94%) offered ideas about nonbiological (external) uses of DNA than could offer ideas about its biological nature and functions (only 6-8% of participants).

Table 4.13

Students' knowledge of nonbiological uses of DNA

Knowledge categories	Sample 1 (*n* = 18)	Sample 2 (*n* = 25)	Sample 3 (*n* = 11)	Sample 4 (*n* = 8)	Totals (*N* = 62) (%)
Solving crime	16	22	5	5	48 (77.4%)
Forensics	9	11	1	4	25 (40.3%)
Paternity	3	17	4	5	29 (46.8%)
Family relationships	5	7	2	0	14 (22.6%)
Diagnosis of disease	3	12	2	2	19 (30.6%)
Other ideas	9	15	3	3	30 (48.4%)

Table 4.13 shows that solving crime was the main nonbiological use of DNA, suggested by 48 students (77.4%). Half of these students mentioned this use first. Only two students mentioned forensics without also mentioning solving crime, focusing on scientists looking at genes to find people. Thus, 23 students associated solving crime and forensics, although these were two separate categories on the interview response sheet (and prompted separately). Only one student, Clarenne, a Year 5 girl from Sample 2, was definite that DNA could *not* be used to solve crime.

> **Genetics Assertion 14: 77% of participants said that DNA could be used to solve crime; this was the first use suggested by half of this group.**

Paternity and family relationships were combined in one category on the interview response sheets and prompted only once, but the students' answers separated into two aspects; one involving tests to resolve parent-child identity issues including adoption cases, and the second, concerning other family members and unknown soldiers. Only three students mentioned both such aspects. Therefore, collectively, 40 students (64.5%) suggested that DNA could identify family relationships in some way. More than one third (15) of the students mentioned this use first. Five of these 15 students suggested it was the main or sole use of DNA, and only one student, Allirea, a Year 6 girl from Sample 4, said that DNA could *not* be used to resolve family relationships.

> **Genetics Assertion 15: 64% of participants suggested that DNA could be used to identify family relationships; this was the first use suggested by more than one third of this group.**

Diagnosis of disease was a category that generally yielded less precise answers and fewer explanations, though two exceptions were Willis, a Year 6 boy, and Shanee, a Year 7 girl, both from Sample 1. Willis described the taking of a biopsy for cancer in these words: "To help diseases. So like if you have cancer in one of your organs, they can take a tiny bit of your organ, freeze it, and then slice it into thin slices and put it under the microscope and then they can see if it has cancer in it, or anything else. Can see if the DNA looks right or not." A biopsy more correctly looks at the cellular and chromosomal levels rather than at DNA, but it was a remarkably accurate and thorough description of the process. Shanee noted that DNA could be looked at to detect breast cancer and diabetes. In all, 19 students (30%) thought that DNA might be useful in diagnosing disease, though only three students put this use first.

> **Genetics Assertion 16: 30% of participants suggested that DNA could be used to diagnose disease; first suggested by only one sixth of this group.**

Nearly half of the interviewed students (48.4%) had other ideas about uses of DNA, of which cloning was the single most popular, mentioned by eight students. Five students mentioned generally identifying people, with two referring to the TV show *Bones*. Five students talked of research or experiments, and two mentioned DNA databases on computers. Three said that doctors might use DNA but were unsure how. One suggested growing the DNA of endangered animals such as the Tasmanian tiger, and another spoke of work he had seen on documentaries involving putting mammoth DNA into elephants, and human DNA into robots. Half of this group mentioned their ideas before offering any of those on the answer sheet.

> **Genetics Assertion 17: 48% of participants suggested alternative uses of DNA such as cloning, identification, and research; half of this group gave their own ideas about uses of DNA first.**

Content analysis as per List (2005) determined in an objective manner the students who represent, in List's words, a "typical" interview for each sample. This process took into account sex, average interview score, and the range of answers for each of the interview questions as summarised in Tables 4.10 to 4.13. Table 4.14 presents salient excerpts from these typical students in their own words.

Table 4.14

The voices of "typical" students in each sample

	Sample 1	Sample 2	Sample 3	Sample 4
Student	Neil, boy, Yr 6, score 19/30	Tallulah, girl, Yr 7, score 18/30	Cathleen, girl, Yr 6, score 17/30	Tirranna, girl, Yr 5, score 11/30
Inheritance	Genes – if you're a boy, your Dad gives his Y gene and your Mum gives her X gene. If both of them have blue eyes, so will you.	Maybe genes – things from inside adults go into the little kitten. If big cats have babies, the same genes are in the babies as the parents.	DNA – I guessed that – babies take samples of DNA from Dad and Mum, but I don't look like my parents, I look like my aunties.	They look the same, but I don't know why. I've heard of DNA but I don't know what it means.
About genes and DNA	DNA makes you different from other people. If a criminal commits a crime, leaves a fingerprint or another DNA sample like blood or spit, police can tell them apart from other people.	Like little particles; both have to do with the body, and having babies, the DNA helps to find out what, where stuff is, I can't really explain it. I saw a documentary on cloning too.	Every living thing has DNA, inside your body. DNA is curly things with coloured dots round it (twisty hand gesture). DNA is to make us all different, even twins don't have the same fingerprints.	Humans have DNA. I think it's in the head. I know it makes something, I don't know what. I think genes and DNA are different because they sound different.
Uses of DNA outside body	Crime, like I said before, and like, on *Find My Family*, if people move away, can find them with a DNA sample.	If you've got a parent who doesn't know if it's their kid you can run a DNA test. Can use it to solve crime if there's fingerprints on stuff.	DNA tells us who we are related to.	Used for pa . . ter . . nity, can use DNA to find out who's the Daddy and yes, to solve crime.

The students in Table 4.14 represent the decreased knowledge students have with declining SES. Neil has the most specific knowledge about inheritance, mentioning X and Y, though incorrectly attributing these to being genes rather than chromosomes. However, his statements about eye colour matched how the media and textbooks represent this trait, although the actual mechanism is more complicated. Neil also went straight into a link between DNA and crime when asked for his spontaneous information about genes and DNA. He reiterated his statements about DNA and crime when asked about outside uses of DNA, and then added information about finding family members, quoting the TV show, *Find My Family*.

Tallulah's knowledge was patchy and typical in that she knew much more about what DNA is used for outside the body than its biological functions. Field notes indicated that she was very hesitant throughout much of her interview, but her answers to the last part about what DNA may be used for, and in telling about the documentary she had seen recently on cloning, were more confidently expressed.

Cathleen gave a very chatty interview, including confessing that she had just guessed the answer DNA, and going into considerable detail about family resemblances. She was quite knowledgeable about DNA, using a hand gesture to show the spiral ladder shape of DNA. This was surprising, given her classroom teacher had suggested that Cathleen was a remedial student, and expressed doubts about her capacity to contribute much to the research. The teacher, in turn, was surprised when told after the interview how much Cathleen knew about genes and DNA.

Tirranna had much less knowledge than the other typical students, reflecting lesser knowledge generally acquired by the students in this sample area. However, she was willing to offer ideas when she was not sure of the information, and knew more about what DNA might do outside the body than what it does inside, even attempting to say the word *paternity*.

2b) What misconceptions do primary students have about genetics?

This section focuses on incomplete and erroneous ideas, that is, misconceptions, which students in this study expressed about genetics. Chapter 2 presented a list of 24 known misconceptions from the international literature, with full details in Appendix A2. The numbers K1, K2 and so on from this list match with expressions of these misconceptions by students in this study. Numbers of M1, M2 and so on, apply to new misconceptions expressed by students in this study.

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Chapter 3 explained what is (and what is not) regarded as a misconception for the purposes of this research, and which known misconceptions were targeted by the interview and counted. Sums of known and new misconceptions expressed by students during this research are summarised in the box-and-whiskers plot in Figure 4.17. Eight students scored zero for misconceptions. Six of these students had low scores for genetics knowledge ($\leq 15/30$), so apparently had not acquired enough knowledge to acquire misconceptions. The other two students had high knowledge scores ($\geq 25/30$) and made no erroneous statements.
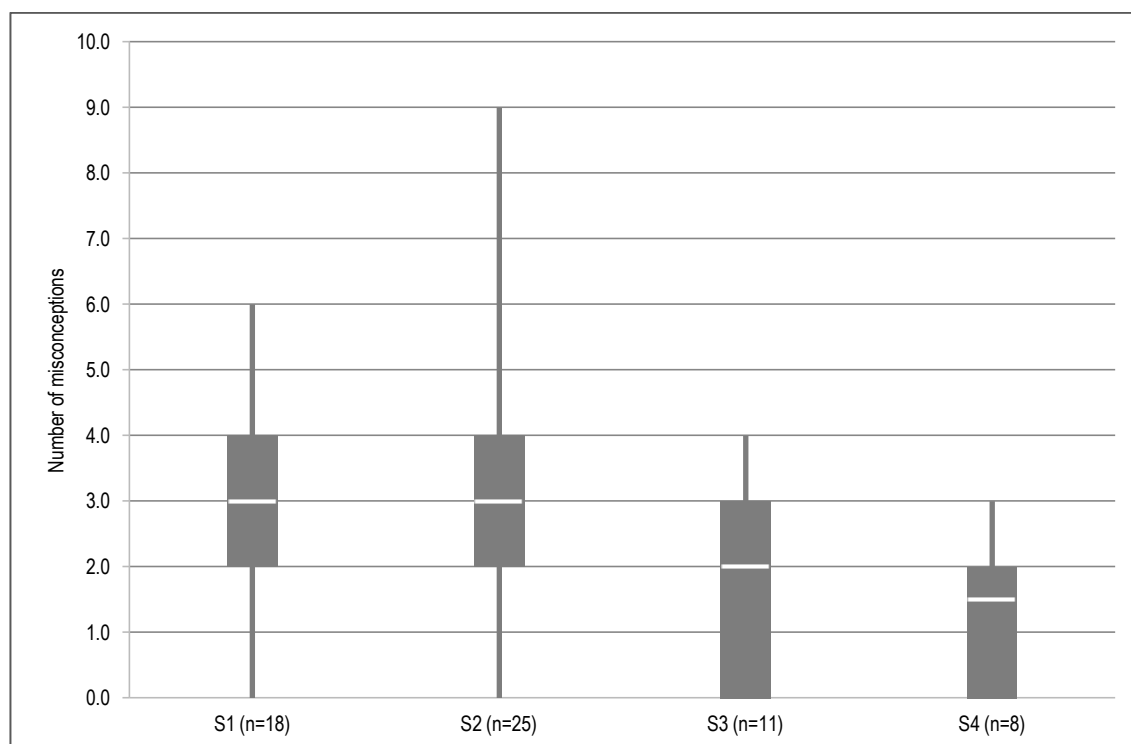
Figure 4.17. Five-figure summary of the numbers of student misconceptions.

Figure 4.17 shows that Samples 1 and 2 shared the same median number of misconceptions, but Sample 2 had a greater range with some students having a maximum of nine misconceptions. Students in the small towns comprising Samples 3 and 4 have fewer misconceptions than their counterparts in larger population centres, with Sample 4 having the least. This trend generally follows that for genetics knowledge, as shown in Figure 4.18, a plot of the average interview scores against the average number of misconceptions in each regional sample, with 95% confidence limits.
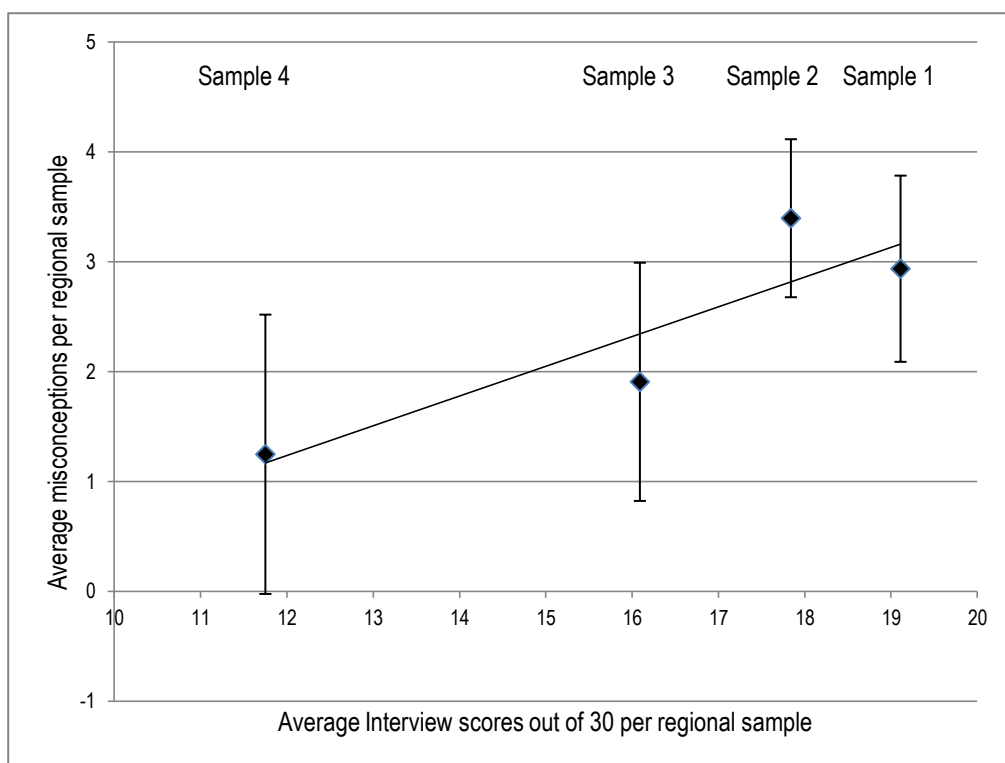
Figure 4.18. Average misconceptions about genetics against genetics knowledge.

Genetics Assertion 18: Generally, participants who demonstrated more genetics knowledge also expressed more misconceptions.

Figure 4.18 shows a general trend that students who have acquired more genetics knowledge have generally also acquired more misconceptions, and indicates that SES correlates with this trend. Sample 3 was again anomalous with fewer misconceptions than predicted from the general trend, and Sample 2 showed more misconceptions than predicted. Field notes and records of duration of interviews show that students in Sample 2 tended to elaborate more on their answers, with their interviews averaging 4.5 min longer than did those of any other sample area. This may explain their higher number of expressed misconceptions. As variances were unequal as shown by Figure 4.17, and average number of misconceptions was low, there was no appropriate statistical test, so no claims are possible regarding significance of this trend.

Probing questions targeted misconceptions concerning the nature and function of DNA and genes. As shown previously in Table 4.12, 17 students (27%) thought DNA and genes were different, representing known misconception 1 (K1).

Transcripts were studied for evidence of K2, the idea that genes are what make you resemble your family, whereas DNA is what makes you unique and identifiable, which had

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been prevalent in previous research (Donovan & Venville, 2004). In this study, 13 students (21%) made comments expressing this belief. Of these students, four were those who scored poorly on the interview (≤ 18/30 though none scored less than 15/30), whereas nine students were those who scored well on the interview, including both students who scored the top mark of 28/30. It is possible that this is a higher-level misconception, reliant on the acquisition of a certain amount of knowledge for its development.

> **Genetics Assertion 19: 21% of participants expressed a misconception that linked genes with family resemblance and DNA with unique identity.**

It is not incorrect to say that DNA is used to solve crime, for this is a scientific use of DNA. However, K3 refers to statements that indicate a belief that this is the *sole function* of DNA, that it has no function in the body. Eight students (12.9%) made statements representative of this misconception.

> **Genetics Assertion 20: 13% of participants expressed a misconception that DNA's only function is to solve crime.**

Nearly all students (97%) knew that humans would have DNA and/or genes, yet the location of these molecules in the body yielded 27 different answers. As described in previous research and in Chapter 2, K4 refers to a belief that DNA is mostly in blood or body parts collected for forensic purposes such as skin, hair, fingerprints, saliva. This study identified another group of students who believed that DNA is confined to only a few internal organs. This misconception became K4', similar to K4 in not knowing that DNA is in nearly every cell, but not selecting parts possibly linked to solving crime. These related misconceptions were by far the most prevalent in this research, with 32 students (51.6%) expressing K4, and a further 11 students (17.7%) expressing K4'. Table 4.15 presents a breakdown of key results (locations mentioned by more than one student).

The results in Table 4.15 contrast with the seven students who knew the correct answer to this question, and the other ten who said *everywhere*. The belief that DNA and/or genes are mostly in the blood was particularly prevalent. All answers involving limited locations were probed further by asking the students, "Are they anywhere else?" but students saying blood usually added other parts suitable for forensics. Furthermore, six students built on this misconception in the section on uses of DNA, indicating their belief that DNA *is* blood, explaining that DNA could be donated to others, and referring to grouping DNA like blood groups.

Table 4.15

Students' misconceptions regarding the location of DNA/genes in the body

	Sample 1 (n = 18)	Sample 2 (n = 25)	Sample 3 (n = 11)	Sample 4 (n = 8)	Totals (N = 62) (%)
Blood	11	13	4	2	30 (48.4%)
Fingers/prints	7	6	1	0	14 (22.6%)
Skin/skin oil	6	4	1	0	11 (17.7%)
Saliva	4	1	0	1	6 (9.7%)
Hair	2	3	1	0	6 (9.7%)
Outside body	0	1	1	0	2 (3.2%)
Excretions	3	0	0	1	4 (6.4%)
Head/eyes	0	4	1	1	6 (9.7%)
Guts/liver/organs	2	4	0	0	6 (9.7%)
Brain	2	2	1	0	5 (8.1%)
Heart	1	1	1	0	3 (4.8%)
Bones	2	0	0	0	2 (3.2%)

This interview did not include specific questions about whether students thought DNA would be in nonliving objects or in other organisms such as plants (K5). However, some students volunteered such information as part of their conversation about genes and DNA. Six students correctly said that genes and DNA would be found in all living things; only one said that plants would not have genes and DNA.

The misconception that genes and traits are the same thing (K6) was also not the subject of a specific question, but this belief was revealed in the answers of three students. Misconceptions K7 and K8 also were not targeted by the questions, but four students suggested that genes make specific body parts (K7), and two students felt genes (or DNA) would only be found where their effects could be seen (K8). One student expressed K9, a deterministic belief that single genes exist *for* particular traits, in this case, for abilities such as swimming.

Table 4.10 indicates that four students expressed K10, the factor concept of inheritance. One student expressed the idea of hidden traits in different generations (K11). Students who had some idea that genes and DNA have a biological function but were unable to state it accurately, held misconception K12. This was the case for 22 students, the second most common misconception in this group. However, this result

was not unexpected, as students are unlikely to find out this information informally; this should be the subject of targeted teaching in later school years.

Specific questions did not probe misconceptions K13-K24; however, five students expressed ideas that girls and boys receive unequal genetic information from their mothers and fathers, though not all expressed it exactly as K18 (that girls get more from their mothers and boys get more from their fathers). All used words such as 'most' or 'nearly all', going beyond the slight size difference between X and Y chromosomes. Further, four students made statements that demonstrated their belief that information from mothers and fathers may be expressed differently (K20), specifically referring to genes for the colours of eyes, hair, and skin.

Numbers of misconceptions were too low for meaningful division into regional subsamples. Table 4.16 summarises the foregoing descriptions with a brief statement of each of the known misconceptions as found in this study, and the number and percentage of participating students who expressed each one.

Table 4.16

Summary of the incidence of known misconceptions about genes and DNA

Misconception	Total ($N = 62$)	Percentage of N
K1 – Genes and DNA are different things	17	27
K2 – Genes- family resemblance, DNA- unique identity	13	21
K3 – DNA's only function is to help solve crime	8	13
K4 – DNA only in blood or forensic samples;	32	51
K4'- DNA found only in a few internal organs	11	18
K5 – DNA not found in plants	1	1.6
K6 – Genes are the traits themselves	3	5
K7 – Genes make a specific body part	4	6.5
K8 – Genes/DNA found only where effect seen	2	3
K9 – Single genes exist for traits such as swimming	1	1.6
K10 – Inheritance due to unchanging particles	4	6.5
K11 - Genes may be hidden in earlier generations	1	1.6
K12 – Ascribe incorrect biological function to genes/DNA	22	35
K18 – Unequal DNA/genes from Mum and Dad	5	8
K20 – Information from parents unevenly expressed	4	6.5

Genetics Assertion 21: 27% of participants expressed a misconception that genes and DNA are different things.

Genetics Assertion 22: 51% of participants expressed a misconception that DNA is only found in blood or forensic samples.

Genetics Assertion 23: 18% of participants expressed a misconception that DNA is only found in a few internal organs.

Genetics Assertion 24: 32% of participants expressed various misconceptions concerning gene expression (K6, K7, K8, K9, K11, K18, and K20).

Besides the slight variations on known misconceptions as described in the preceding paragraphs, students in this study expressed 18 new misconceptions, adding to the list of misconceptions as recorded in the literature. Although individual students expressed some misconceptions, small groups of students, not necessarily from the same sample area, expressed other misconceptions. Table 4.17 explicates these novel misconceptions, divided into three groups in terms of area of misunderstanding, and shows how many of the 62 interviewed students expressed each one.

Table 4.17 shows that there are wide-ranging beliefs concerning DNA and genes. Some of the more widespread beliefs are of greatest concern. Four times more students expressed misconceptions about the function of DNA and genes than about its transmission or nature. Misconceptions about functions were mostly limiting; beliefs that DNA or genes have only one function, mostly concerned with ways in which DNA may be used in society, such as for identifying people and solving family relationships. This is not its biological function. Another prevalent misconception about function is deterministic; although 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 traits is inaccurate. In addition, although DNA undoubtedly contributes to how a person looks, it is not the only contributing factor. The influence of the environment must also be considered. It is this element of the contribution of the environment, the "nature versus nurture debate," that is missing from the students' ideas about genes and DNA. Reconstruction techniques exist to create likenesses of people from bones for example; but this is done on the basis of

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comparative anatomy, not by "reading" their likeness from the DNA in some way, as implicit in misconception M3.

Table 4.17

Incidence of novel misconceptions amongst the interviewed students

Novel misconceptions	Number (*N* = 62)
Misconceptions about the function of DNA/genes	**27 (44%)**
M1 - DNA's main function is to determine and resolve family relationships	8
M2 - DNA/genes determine how we behave, act, think, personality	6
M3 - DNA determines looks, DNA sample shows what people looked like	5
M4 - DNA's only function is to identify you and make you who you are	4
M5 - DNA can be used to change colours of hair, eyes, skin	1
M6 - DNA develops body parts when older that you didn't have as a kid	1
M7 - DNA doesn't have a function, we just have it	1
M8 - Genes/DNA is only to do with ageing	1
Misconceptions about the transfer of DNA/genes	**7 (11%)**
M9 - Genes pass to kitten in mother's uterus in same way as food does	2
M10 - Girl and boy genes are injected into kittens	1
M11 - DNA works through fluids from the mother	1
M12 - Genes passed on through mother's milk	1
M13 - DNA transferred when Mum inhales skin cells that have flaked off	1
M14 - Genes go into the air	1
Misconceptions about the nature of DNA/genes	**5 (8%)**
M15 - DNA has to do with blood oxygen content and colour of blood	2
M16 - Genes are the same as gender, boy and girl	1
M17 - DNA looks like saliva and if it's yellow . . . you're sick	1
M18 - DNA is dangerous and kills people	1

Genetics Assertion 25: 44% of participants expressed novel misconceptions concerning gene/DNA function (M1-M8).

Table 4.17 also shows that mechanisms of transfer of genes/DNA are a problematic area for several students. Some appear to have extrapolated from what they know about other items transferred between parents and offspring, resulting in misconceptions M9,

M11, and M12. However, others are more creative in nature, such as misconceptions M10, M13, and M14.

Genetics Assertion 26: 11% of participants expressed novel misconceptions concerning transfer of genes/DNA (M9-M14).

As seen previously, many students thought DNA was in the blood, or was the same thing as blood, but two students linked it with the colour, specifically the oxygenation of blood, which was a new idea seen in M15. Linking DNA with yellow saliva and illness, as in M17, was a novel idea, as was the notion that DNA is dangerous and kills people (M18). These students were the only ones ascribing negative effects to DNA.

Genetics Assertion 27: Eight percent of participants expressed novel misconceptions concerning the nature of genes/DNA (M15-M18).

A search of the transcripts revealed two students from each sample whose voices best represented the misconceptions common to that sample group. The first set of four students, in Table 4.18, comprises all Year 5 boys, forming a comparison of the thinking of students of this age and sex in the different sample areas. The second set of four students, in Table 4.19, is more diverse in age and sex. All scored higher in the interview than their counterparts in Table 4.18.

Table 4.18 highlights how much more Carsten (Sample 2) had to say compared with his counterparts from other samples. This was typical of the interviews from the students in Sample 2. Only some of his stated misconceptions are in Table 4.18; he was very creative in his ideas. His comment that just because he is IN a girl doesn't mean he will BE a girl is quite perceptive, and not a factor any other student raised.

In Table 4.19, Prasai's interview was particularly interesting. He emigrated from Malaysia two years previously, and said that they had discussed genes and DNA in Years 1 and 2 of school there. He knew more than most students, attaining the equal top score on the interview. He was very willing to share his guesses and ideas as well as his knowledge. He expressed misconceptions mostly when guessing, or unsure. In this second set of students, useful knowledge that gained them their higher interview scores often coincided with misconceptions, requiring probing questions to find out what they really thought.

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Table 4.18

The voices of the first set of selected students expressing misconceptions in each sample

	Sample 1	Sample 2	Sample 3	Sample 4
Student details	Tobias, Year 5 boy	Carsten, Year 5 boy	Arunta, Year 5 boy	Parri, Year 5 boy
Interview score	21	16	14	11
Misconceptions	3	9	3	3
Location of genes and DNA	I'm not sure . . . bones, blood	Well, DNA is like a sample, like with the cat, like a piece of skin, a piece of fur, a vessel. I think . . . it might be in the blood, that produces different blood colour . . . and that's down to whether the skin's blood is dirty, whether it's got enough oxygen in it.	DNA is blood types and fingerprints, but it's found everywhere.	No idea. I've heard of DNA, I know police use it.
What genes and DNA do	I'm not sure . . . I think it's just – it makes you who you are, it makes you different. It's from your past relatives.	I got my DNA from my Mum and Dad. Mostly my Dad. I guess really because my Dad's a boy, and I'm a boy, and my Mum's a girl . . . just because I'm IN a girl, doesn't mean I'm going to BE a girl. Cause my Mum could inhale . . . something like . . . skin . . . skin cells? that flake off and that could come into the lungs, go through some sort of way and ..	DNA helps us to identify us. *How does it work?* I don't know.	Only some humans have DNA. I think DNA is dangerous, it kills people.
Similar or different?	Probably different (uncertain tone). *Any idea of how?* No.	I probably think they're a bit different.	I don't know genes, so I don't know.	Different cause they look different and they're produced different.
Uses of DNA outside body	I know that they can use it . . . there's technology now, you can get the bones, get the DNA, do a special scan and actually find out what the person looks like.	To clone animals . . . to clone people . . .	It can find out criminals and relatives.	Crime. On *Bones* they use DNA to find out who the murderer is.

Table 4.19

The voices of a second set of selected students expressing misconceptions in each sample

	Sample 1	Sample 2	Sample 3	Sample 4
Student details	Prasai, Year 6 boy	Cherry, Year 7 girl	Eliza, Year 6 girl	Burnu, Year 7 boy
Interview score	28	21	21	17
Misconceptions	3	9	4	1
Location of genes and DNA	When the kittens are in the womb . . . I think it's like when the mother eats food and it is transferred to the kittens, I think genes and DNA are transferred into them too.	Blood in you. There's different groups of DNA. DNA might be your personality, image, what you look like, facial features, height, build, all these things are the genes and DNA.	Genes and DNA are both in my brain, and heart. I seen on TV that DNA looks like two pieces of wire that have been bent with little balls in between.	(Long pause) Blood
What genes and DNA do	Genes come from mother's mother and mother's father and kind of merged into one gene. DNA can tell you how you look.	Cells from both parents are mixed into one, but there may be more of the Mum's or Dad's genes. They make you resemble your parents, identify you with your parents. The genes and cells stick together and blend into one person.	Genes can be passed way through generations, like if your great great grandfather has cancer, you might get it, even if it missed in between. DNA could be for your health, like healthy levels of blood sugar.	I don't really know, it comes together with other DNAs.
Similar or different?	Kind of similar. DNA I think it kind of tells us what the person will look like, and genes, are from your family relations and are passed down.	Different. Genes are like from your parents but your DNA is like your blood, and it's got a little bit of your parents in it but it's mainly like yours.	I think they're similar, because they both have something to do with your body.	I don't know genes, so I don't know.
Uses of DNA outside body	Scientists could use a very technical, advanced computer and get samples of DNA that might be on fingerprints, and use the computer to find out how the person looks like.	We can donate DNA blood to people. We can use DNA as evidence, like if someone's been stabbed. We can run tests on suspects.	Crime, everyone's got similar and different genes in their fingers, so we can go by fingerprints in crime. It can be used at the hospital, to find out what type of blood you've got.	Cloning. Crime. (Said *yes* to question about forensics, and *I think so* to paternity question).

This section has shown that the participating primary students mostly know about genes and DNA, are forming some ideas about what these entities are like and what they do, and know quite a lot about how DNA is used outside the body, particularly for solving crime and connecting families. That this occurs long before formal education about these topics means these students are acquiring this information informally, and acquiring misconceptions as well as useful knowledge. Some of these misconceptions probably arise as students try to fit newly acquired information into their existing conceptual frameworks; for example, Prasai explained that kittens may get genes from their mothers in the same way as they get food from her in the womb. This finding leads to the examination of where students themselves perceive they have obtained this informal knowledge.

Research Question 3 - Students' Perceptions of Information Sources

From where do primary students believe they have learned about genetics?

This question, asked towards the end of the interview, ascertained students' perceptions of their sources of genetics information. A note was made of the sequence in which students mentioned these sources, on the basis that the category of first response is likely to be the most significant to them. Chapter 5 considers this information on an individual basis, seeking connections between students' perceptions of sources of information, and their conceptions/misconceptions, particularly their beliefs about the uses to which DNA may be put outside the body. Notes were made of which sources students spontaneously mentioned, and which were the result of prompting by the interviewer.

Some students elaborated on their answers for the prompted categories, indicating that some uses of books and the Internet were to conduct their own research into genes and DNA. Some indicated that their interest was sparked by what they had seen on TV, others said it was in response to the prospect of involvement in this research. In all, 17 students (27%) indicated they had done their own research into genetics.

Figure 4.19 displays results for the sources question as stacked columns comprised of the summated responses for the four regional samples. Note that students in Sample 2 often referred to their former school in the *school* category, as, being a new school; the interviewed students had spent from three to five years in other schools before moving to this one. The *other* category includes grandparents, family friends who were police officers and medical personnel.
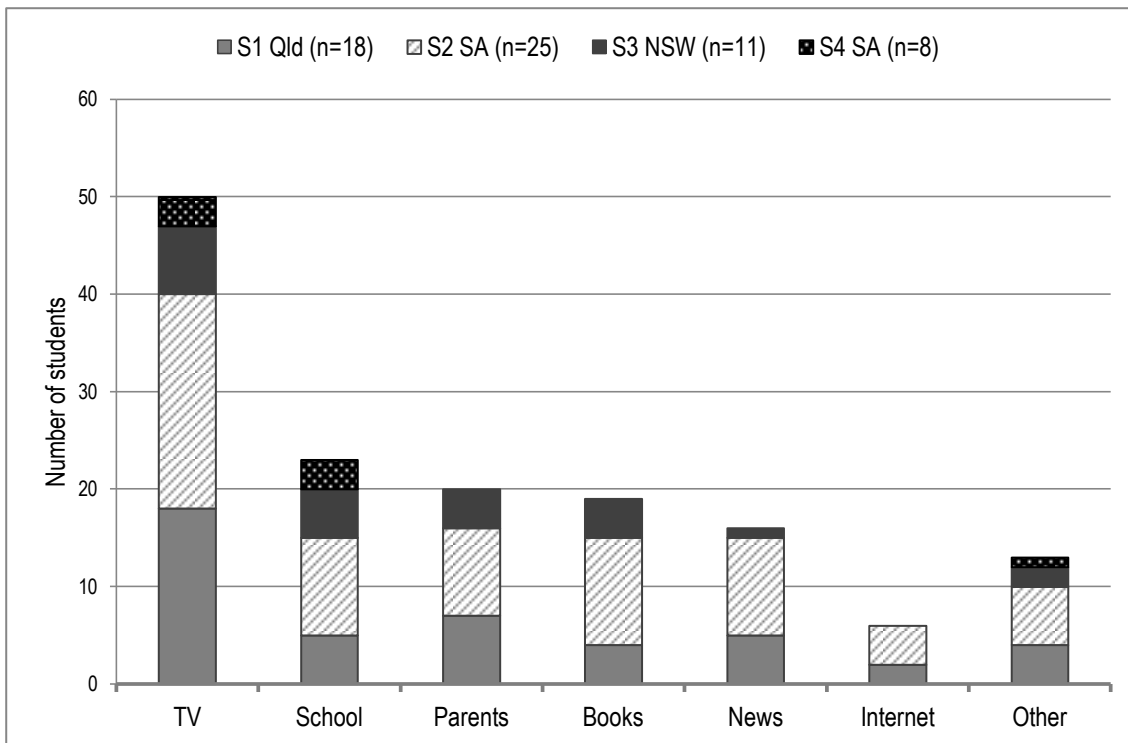
Figure 4.19. Students' perceived sources of information about genes and DNA.

The most striking feature of Figure 4.19 was the paucity of sources for the students in Sample 4. They claimed to have received all their information about genes and DNA from television, school and a grandparent. Field notes indicated that several students in this sample looked taken aback when asked if they discussed such things with their parents, apparently this is not the cultural norm in this small town. One student spelled it out thus, "No, we only talk about everyday things in our house, like what I want for lunch!" The student who mentioned her grandma was asked about the context of this conversation. She explained she had overheard her mother and maternal grandma discussing the body shape of her aunt (her mother's sister), as in her grandma saying, "She's skinny because she's got my genes." In all, six students mentioning parents or other relatives explained they had overheard conversations about genetics rather than directly participating in them.

One student in each of Samples 1 and 2 also said they had not talked to their parents about genetics, with the comments, "Not exactly something I normally talk about with them," and, "I don't really think I'd talk about that with my parents, we don't often talk about things like that." Three students who mentioned their parents as a source elaborated that what they had all watched on TV was the stimulus for the discussion.

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Sources Assertion a: Only 20% of participants reported learning about genetics from their parents, and for half of them, it was through overhearing adult conversation rather than direct discussion.

Sources Assertion b: 81% of participants named television as a source of their knowledge about genes and DNA.

Sources Assertion c: Students in the lowest SES sample (Sample 4), had the fewest perceived sources of genetics information.

Teachers in all schools were asked whether they could recollect directly talking about genes and DNA in planned lessons. They all said no, as it is not part of the curriculum, but suggested they might have raised it in passing occasionally. It was not possible to follow up the previous schools that students in Sample 2 had attended before transferring to this new private school. Students mentioning school spoke of health lessons, movies shown at school, and research conducted for science projects. Others had looked it up in the school library to satisfy their own curiosity, some in Sample 3 taking an interest when considering possible participation in this research. Some students from Sample 2 said that genetics had arisen in classroom conversation, such as when discussing the "Jeans for Genes" charity campaigns.

In all samples, television was the main source, mentioned more than twice as often as any other, named firstly by 23 students (37%), and secondly by a further 18 (29%). For nine students it was their only source, so TV is perceived to be the most significant source by far, for the participating students.

Sources Assertion d: 37% of participants named television as their first source of genetics information and a further 29% named it as their second source.

Only eight students who mentioned any sources did not mention TV, and four students had so little knowledge that they could not give any sources at all. I asked students to elaborate on which types of TV shows they felt had been most influential. Table 4.20 summarises the students' responses to that question. Some students mentioned several types of TV shows, so the numbers do not add to the total number of 50 students who perceived that television was a source of genetics information. Percentages in Table 4.20 refer to that subsample of 50 students.

Table 4.20

Students' specific sources of information about genes and DNA from television (n = 50)

Television shows volunteered as sources	Number of students (and percentage)
Crime shows (general or specific)	**29 (58%)** total including
• *Bones*	9
• *NCIS*	7
• *CSI*	4
• *Law & Order*	4
• *Criminal Minds, The Bill* etc.	5
The News	17 (34%)
Documentaries (SBS, Discovery channel)	12 (24%)
Science shows (such as *Catalyst*)	10 (20%)
Find My Family	7 (14%)
Medical shows (such as *Grey's Anatomy*)	6 (12%)

Table 4.20 shows that these students perceived crime shows to be the main sources of their television knowledge, with *Bones* and *NCIS* being most popular, although *CSI* and *Law & Order* were not far behind. More students mentioned *The News* than was anticipated. Given that TV news is usually a brief snippet of a newspaper report, and that newspaper reports rated poorly for accuracy as detailed in this research, the quality of information obtained from this source is questionable. It was interesting to see that young students watch and pay attention to documentaries and science shows. However, their answers indicated that medical shows should have been included on the questionnaire.

This section shows that students recognised the influence of television on their acquisition of knowledge about genes and DNA, and specifically acknowledged crime shows as a major source of information. Some acknowledged that they had informally acquired information from novels and magazines, however, that some 17 students (27%) stated that they have done their own research on the Internet and in books about genetics demonstrates their interest in these topics at this age. Willis, a knowledgeable Year 6 student, explained how to use Google for this purpose.

Sources Assertion e: Some learning from books was incidental, but 27% of participants reported having done their own research into genes and DNA using books and/or the Internet.

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Situating the Data in the Literature

In the absence of comparative Australian data, these results are compared with American children, who have been the subject of considerable media research. These findings were described in Chapter 2. Rideout et al. (2010) found that on average, American children were using media for 10 hr 45 min per day, but were multitasking 29% of that time, resulting in 7 hr 38 min per day of occupation with the media. On average, the participating students in this research were occupied with media for 5 hr 15 min per day, less than their American counterparts. A possible reason could be a difference in lifestyles, with the semirural environment and generally dry weather that these Australian children experience possibly encouraging more outdoor pursuits.

Rideout et al. (2010) also found that TV was the most dominant medium, and that *tweens* aged 11-14 used most. This study's findings were similar, particularly as the amount of TV viewing increased with increasing age, with Year 7s (aged 12) watching significantly more than Year 5s (aged 10, pre-tween).

Rideout et al. (2010) also reported that computer use was typically ≥ 1.5 hr/day. How much of that time was for use of the Internet was not specified. The Internet was reported as being mostly used for social networking and sites such as YouTube. In this study, Internet use as a medium was of more interest than overall computer use, and these students used 50 min/day of Internet. The most popular individual sites were YouTube, Google, and Facebook, so the Australian students' use is similar. Rideout et al. (2010) found that 84% of American children have Internet at home. This question was not directly asked in this study; however, no students specifically indicated they did not have Internet access at home, although five students out of the whole sample said they never spend time on it. If this situation was due to lack of access, then this study sets Australian home access to the Internet at 96%. Van Evra (2004) found that American rural children are less likely to have a computer at home.

Rideout et al. (2010) found that boys use more computer as they do not grow tired of games, and use more E-games on consoles, peaking at ages 11-14 years. In this study, boys used significantly more media, particularly the Internet (and many of the websites mentioned were games sites), and played more console E-games than did girls. In addition, Year 6s (aged 11) played significantly more E-games than Year 5 or

Year 7 students. Again, the Australian findings are generally consistent with those from the USA.

Van Evra (2004) indicated that low SES children tended to use more media. In this study, findings for low SES areas were clouded by an unexpected marked variation between the two small-town samples. The New South Wales sample (designated Sample 3) appeared to be anomalous in a number of aspects, whereas the South Australian Sample 4 appeared to "fit" better with the others. From Van Evra's (2004) statement, based on many different American studies, it appears that the judgement of the NSW sample as being anomalous was appropriate, and the true trend is an increase in media usage with declining SES.

Anderson and Collins (1988) hypothesised that students may learn from entertainment TV and that it may stimulate their interest in academically relevant areas. In this study, some students specifically stated that what they had seen on TV about genes and DNA had piqued their curiosity, leading to discussions with their parents, and to their own research about genetics in books and on the Internet. Van Evra (2004) also stated that TV is the main source of information for low SES children whose parents do not coview and thus provide extra information. Results are similar in this study, as the students in Sample 4 perceive TV to be the main source of their information about genetics, and rarely, if ever, talk to their parents about it. The finding that only 10% of the students actively discuss genetics topics with parents also fits with the findings of Weiner, Silk, and Parrott (2003) which concluded that families seldom discuss genetic issues at all.

It appears that the findings from these Australian students are comparable with the findings for American students. The major difficulty with such studies is the reliability of self-reported usage; in this case, the method of asking what they *usually do* appears to have produced at least as reliable results as other methods used in USA, which have included parental input, keeping media diaries, and marking television guides. Most students appeared to answer honestly, taking their time to consider the questions, and care to complete the questionnaire properly. Only one student out of 141 filled in some answers in the questionnaire and then erased them, not wanting his responses counted. Despite the pencilled indents being visible, his wishes were respected and his responses to those questions not considered in the analysis.

In terms of their genetics understandings, the participants in this study are generally comparable with those from metropolitan areas interviewed for our previous research (Donovan & Venville, 2004; Venville, Gribble, & Donovan, 2005). The lower SES students in this study, particularly Sample 4 students, were somewhat less knowledgeable than metropolitan students, but also had fewer misconceptions. In particular, the levels of understanding about inheritance of participants in this study fitted with expectations based on our previous research and that of others such as Springer and Keil (1989). Participants also expressed many of the 24 previously identified misconceptions (K1-K24) even though the interview questions did not specifically probe for at least half of them. Participants also expressed 18 novel misconceptions grouped into three aspects of confusion: about the function of genes/DNA, the transfer of genes/DNA, and the nature of genes/DNA. This finding, when published, will increase researchers' understandings of how primary students think about genes and DNA, and will help teachers to detect students who hold these ideas and challenge these ideas more effectively.

No previous research has probed primary students' perceived sources of information about genetics topics so these findings are entirely new. The heavy reliance on television was predictable given the participating students' overall media usage; but school was cited more often than expected, given these topics are not part of the curriculum. Students reported that at least some of this learning was from incidental classroom talk, a reminder to teachers that this chatter may be more influential than perhaps thought. The finding that 27% of the students had been motivated to do their own research about genes and DNA using books and the Internet was unexpected.

Chapter Summary

This chapter reported on students' usage of the media in terms of frequency and duration, on the specific media that the students reported as favourites, and the genetics content of these examples. Students may be exposed to frequent mentions of genes and DNA in a wide variety of media programming, but particularly in television shows, magazines, newspapers, and movies, including news and advertising as well as entertainment programs. Minimal genetics content was found in E-games, radio, and comics, and in the specific websites mentioned by students. However, it was not possible to tell if students had seen items such as the Mitre 10 DNA-based advertisement on the students' most popular site, YouTube, or whether they accessed

genetics websites from Google. Those like Willis, who reported doing their own research into genetics, probably used Google, it being one of their favourite sites.

This chapter reported the participating students' understandings and misconceptions about genes and DNA in detail. DNA was better known than genes, and chromosomes were hardly known at all. Some students had very little knowledge whereas others could describe complex processes such as taking a biopsy or comparing DNA using a database in order to identify the person from the DNA sample. Most offered ideas on how DNA is used outside the body for activities such as solving crime, but had much less knowledge of the biological nature and function of genes and DNA. None mentioned the nucleus of cells as the location of DNA, or proteins as the way in which DNA and genes exert their effects. Few offered any ideas about the role of the environment in moderating the influence of genes on the developing person, but tended to express deterministic views of genes being *for* a wide variety of traits. The most common misconception was that DNA was only found in blood, in other body areas sampled for forensic purposes, or confined to just a few inner organs. As well as previously known misconceptions, this group of students expressed 18 novel misconceptions. This chapter also reported on students' perceived sources of information about genetics, of which television was the most commonly cited.

In particular, the findings within this chapter were summarised into 22 Media Assertions (I-XXII), 27 Genetics Assertions (1-27) and 6 Sources Assertions (a-f). Collectively, these assertions indicate that the students perceive television, and particularly crime shows, to be the major source of their informal knowledge about genes and DNA. This finding lends initial support to the idea that the mass media influences the understandings of genes and DNA of primary students. These assertions guide the cross-referencing addressed in Chapter 5, in which new data regarding the *10 TV shows of interest* and detailed analysis of TV show transcripts is added to the data reported here. The assertions from Chapters 4 and 5 are the basis of the discussion in Chapter 6, the implications and limitations of which are discussed in Chapter 7.

Chapter 5 – Findings and Discussion of Research Question 4

Research Question 4 - Interconnections

Chapter 4 presented relevant data to answer to research questions 1, 2, and 3. Collectively it painted a "big picture" view of media exposure and genetics knowledge in diverse Australian students aged 10-12 years. This chapter seeks to answer Research Question 4, that is, what connections exist between genetics concepts in the media, participating students' reported media use, and their genetics conceptions? To do so it first compares themes across different media and provides further detailed analysis of specific media samples, namely the three TV crime shows that frequently depict the use of DNA (*CSI, NCIS,* and *Bones*). This analysis informs the intensive cross-referencing and constant comparative analysis (Creswell, 2005) of genetics concepts in the media with the data sets related to media usage and genetics understandings for the 62 interviewed students. To distinguish assertions based on this detailed analysis and cross-referencing from those already formed in the answering of research questions 1, 2, and 3, all assertions in this chapter will be termed 'comparative' assertions.

Connections between Concepts in the Media and Students' Concepts

Themes.

Chapter 4 established (Media Assertion XV) that 11 genetics-related themes initially emerged from analysis of 102 newspaper articles. The themes were unknown at the time of the interviews, so the interview questions did not attempt to elucidate students' ideas concerning the themes. Nonetheless, given the opportunity to express their spontaneous knowledge about genes and DNA, some of the themes (such as archaeology and other organisms' DNA) were apparent in the students' responses. Others such as disease, solving crime, paternity were more pointedly elicited by questions about external uses of DNA. The theme of cloning was added due to the students' mentioning of it, and a repeat search of the 102 newspaper articles showed that one article mentioned cloning in passing, as did episodes of the TV shows *Futurama*, and *Family Guy.* Table 5.1 brings together how these 12 themes are represented in each of the main genetics-containing media types, newspapers, magazines and television, ranked in order of their relative frequency in newspapers, whereas Table 5.2 shows how the 12 genetics-related themes are reflected in the participating students' statements.

Table 5.1

Commonality of genetics themes in three media types in frequency order based on newspapers

Genetics themes	Articles from local newspapers related to each theme	Magazines mentioned by students that have articles related to each theme	Television shows mentioned by students including content related to each theme
Disease	Articles on autism, Alzheimer's, fragile X	Articles in "real life" magazines	Hospital shows e.g. *Grey's Anatomy*
Crime	Articles e.g. "DNA nabs rape duo" *Sunday Mail*[58]	Articles e.g. "DNA tests prove Maddie's body was moved" *Woman's Day*[24]	Crime shows e.g. *CSI, NCIS, Bones*, also *Home and Away, Futurama*
Other organisms	Articles e.g. "GM wheat has no place on the menu" *Western Herald*[59]	Articles mentioning GM e.g. "What's your eco footprint?" *Better Homes & Gardens*[29]	*Futurama, Big Bang Theory*
Nonscience	Articles e.g. "Harry Potter confronts the test of time" *Western Herald*[36] claiming Roald Dahl's DNA is in Harry Potter	Articles e.g. "Putting the muse in musician" *Girlfriend*[19] claiming that is what DNA does	*The Simpsons*
"Good" genes	Articles e.g. "Niceness is in your genes: study" *Sunday Mail*[41] based on twin studies	Articles e.g. "Take years off your telomeres" *Women's Weekly*[21] about ageing	*Big Bang Theory*
Diet, weight, fitness	Articles e.g. "Diet's in your blood and in your genes" *Sunday Mail*[42] about the GenoType diet	Articles e.g. "Belt tightening" *Better Homes & Gardens*[28] about beating genes and lose weight	*The Simpsons*
Genome sequencing	Articles e.g. genomes of other organisms such as ancient birds[43], Antarctic krill[44], flea[45]		*Big Bang Theory, Family Guy*

Genetics themes	Articles from local newspapers related to each theme	Magazines mentioned by students that have articles related to each theme	Television shows mentioned by students including content related to each theme
Archaeology	Articles e.g. "DNA finding reveals Asians in Roman Empire" *Sun Herald*[48]		*Futurama*[61]
Family relationships	Articles about disputed paternity including Monaco Prince[49]	Short snippets in *Woman's Day* & TV guides about celebrity paternity cases	*Find My Family, Can We Help? (Lost and Found), Neighbours, Futurama*
Personal identity	Articles about adoption issues[31, 32]	Articles e.g. "We're dentists for the dead" *That's Life!* [26] about using DNA to identify dead people	*The Simpsons, Big Bang Theory*, news
Sex/gender	An article about using a chromosome test to check if an athlete is female[53]	Articles e.g. "Why boys and girls are soo different" *Girlfriend*[19]	
Cloning	An article about stem cells[60].		*Family Guy, Futurama*[61]

Comparative Assertion A: Similar themes about genetics emerged from all three types of genetics-containing media used by participating students, that is, newspapers, magazines, and television.

Table 5.1 shows that not all themes were equally represented in all three media, but all were found in at least two forms. Where newspapers may attempt to present a scientific view, of DNA's use in archaeology for example, animated TV shows such as *Futurama* take the concept to extremes. For example, in the episode *Jurassic Bark*[61], lead character Fry visits an archaeology exhibit in a museum and sees his fossilised dog. He is overjoyed to find that the dog's DNA is sufficiently preserved for cloning. However, believing that the dog lived several years after his sudden departure for the future, and would have found a new owner and forgotten him, he chooses to abort the cloning attempt. A sad final flashback shows that the dog remained faithfully waiting for him for years until its death. This episode neatly combined two of the themes, DNA in archaeology and cloning.

Table 5.2 shows how the genetics themes that emerged from the media analysis corresponded with statements about genetics made by the interviewed students. The themes are ranked in order of frequency of incidence in student statements. Just one theme found in the media was missing from the student statements; this was the theme of how genes relate to diet, weight loss, and fitness. Participating students aged 10-12 may not find this information particularly interesting or relevant to them.

Table 5.2

Cross-tabulating genetics themes from media with students' knowledge

Theme	Students mentioning each theme	
	Number (N = 62)	Percentage
Nonscience	54	87.1 (held misconceptions)
Crime	48	77.4 (both solving and forensics)
Family relationships	29	46.7 (mostly paternity)
Disease	19	30.6
Personal identity	14	22.6 (mostly adoption)
Cloning (added)	8	12.9
Genome sequencing	5	8.1 (research, experiments)
Other organisms	4	6.4 (mostly dogs)
"Good" genes	3	4.8 (related to health)
Sex/gender	1	1.6
Archaeology	1	1.6 (identifying people from the past)

Table 5.3 shows a comparison of the rank order of incidence of the genetics themes in newspaper articles and the students' answers.

Table 5.3

Cross-tabulating rank order of genetics themes from media with students' answers

Themes	Incidence in newspapers	Incidence in students' answers
Disease	1	4
Crime	2	2
Other organisms	3	8
Nonscience	4	1
"Good" genes	5	9
Diet, weight and fitness	6	-
Genome sequencing	7	7
Archaeology	8	11
Family relationships	9	3
Personal identity	10	5
Sex/gender	11	10
Cloning	12	6

Comparative Assertion B: The same genetics themes that emerged from the mass media were found in participants' expressed genetics knowledge.

Collectively, Tables 5.1, 5.2, and 5.3 indicate that the themes about genetics that prevail in the mass media were mentioned by students during their interviews. However, the rank order of incidence of these themes differs, possibly reflecting students' greater interest in crime, personal identity, families, and cloning than in disease. Care was taken to look for genetics information supplied by participating students that could not also be found in media to which they had been exposed; none was found other than novel misconceptions as described in Chapter 4, which mostly consist of incomplete information or incorrect attempts to combine information.

The remainder of this chapter explores interconnections in detail, mainly by comparing the content of the *10 TV shows of interest* (7 crime and 3 family relationship shows), with the contents of participating students' interview statements. Throughout this section, analysis of the crime shows precedes that of the family relationship shows. Firstly, data are presented showing the degree of student viewing of these TV shows.

Secondly, the contents of these TV shows are analysed, generally, and then in-depth, including relevant partial transcripts. Lastly, genetics-related concepts in these TV shows are brought together with the participating students' statements about their genetics conceptions and sources of genetics information.

Student viewing of the 10 TV shows of interest.

Weighted scores (described in Chapter 3) representing how often students had viewed each of the ten shows were summed for all 62 participants as shown in Figure 5.1. Only nine students (14.5%) had watched none of these shows, and eight students (13%) had watched just the family relationship shows, not the crime shows. It is important to note that the participating students were aged 10-12 years, yet the seven crime shows of interest are all rated as suitable for ages 15 years or older and screened at 8.30pm or later. However, 13 of the 17 students who did not report viewing crime shows said they had viewed other genetics-containing TV shows such as *The Simpsons,* medical shows, documentaries, other crime shows, and science shows. Of the four remaining students, two chose not to answer these questions, one had only overheard her parents discussing genetics, and one had learned about DNA from his previous school in Malaysia and from his own research. In total, only 13 students (21%) made no mention of any crime shows in their questionnaires or interviews.
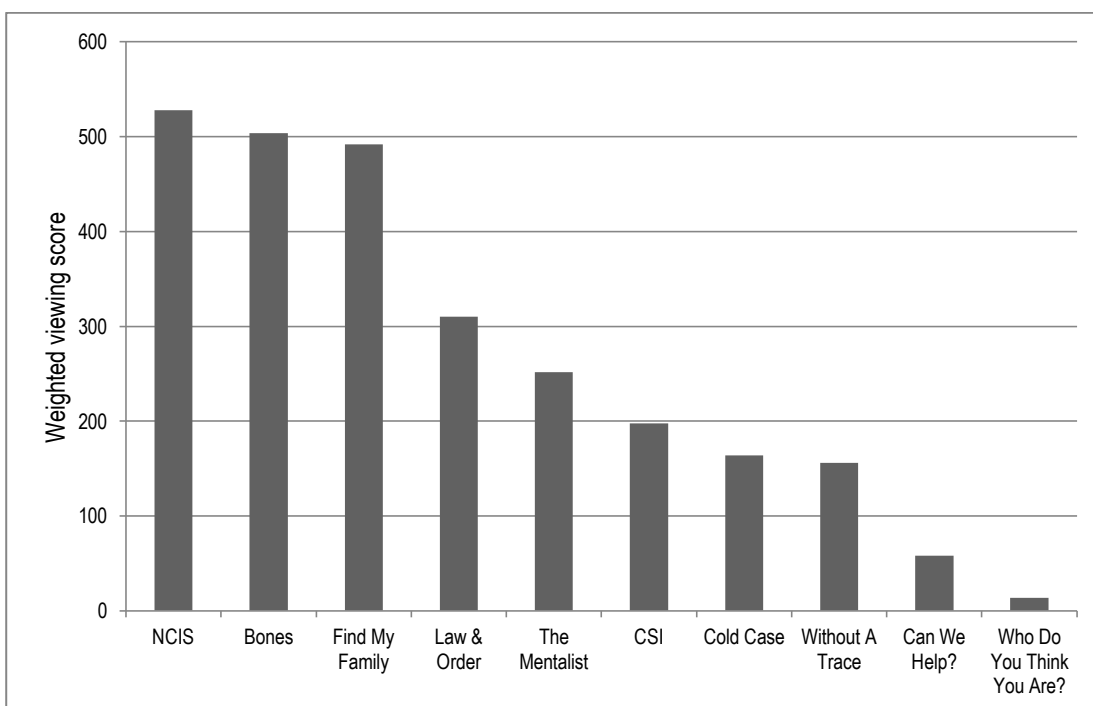
Figure 5.1. Relative viewing levels of 10 TV shows of interest by 62 participants.

The data in Figure 5.1 do not show a clear-cut case of popularity, as not all of the TV shows of interest were available free-to-air in all the sampling locations. Samples 3 and 4 (*n* = 19) lacked access to the channel that screens *Law & Order,* and *NCIS*, making its rate of viewing all the more remarkable. Sample 2 (*n* = 25) lacked free access to *CSI, The Mentalist, Cold Case,* and *Without a Trace.* Despite that, a few students in locations lacking free access to TV shows watched them as their parents had bought DVDs or downloaded the individual shows from TV station websites. The TV shows *Bones, Find My Family, Can We Help?* and *Who Do You Think You Are?,* were freely available to all students.

Comparative Assertion C: Crime shows have been viewed by most (79%) of the participating students, with *NCIS* and *Bones* being the most viewed shows.

The data indicated that students view whichever crime shows they had available. Thus, although data collection in different regions anticipated differences due to the presence or absence of specific TV channels and hence crime shows, differences in genetics knowledge could not be quantitatively matched to specific shows by regions. Attempts were made to examine quantitatively the relationships between those who watched the shows of interest most often and their specific genetics knowledge. However, no consistent patterns emerged from the data.

Crime shows – general analysis.

As described in Chapter 3, preliminary sampling of television shows to guide the design of the media questionnaire revealed that *CSI*, *NCIS*, and *Bones* mention DNA most often; on average, in every other episode. All three shows feature the workings of crime labs, have forensic scientists as key characters, and depict the sampling and use of DNA to solve crime. As a result, these three TV shows are the major focus of this section. Other crime shows of interest such as *Law & Order, The Mentalist, Cold Case,* and *Without a Trace* mention DNA far less often, do not feature forensic scientists, and are not set in a crime lab. However, one episode of *Law & Order: SVU* has been included, as a new real-life DNA discovery is central to its plot[71].

To set the scene for the analysis, general descriptions of the discourse and visual aspects of these crime shows are provided. Transcriptions were limited to those parts of a TV show referring to genetics topics. In all, 10 such transcripts were produced, three from each of *CSI, NCIS,* and *Bones,* and one from *Law & Order: SVU.* Three of the transcripts are presented here in full, others are described.

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At the broadest level of discourse analysis, the transcribed excerpts were noticeably similar. When analysed using Hymes' (1974) SPEAKING grid, it was possible to derive a single generalised grid as shown in Table 5.4.

Table 5.4

Generalised SPEAKING grid derived from 10 TV crime show excerpts

Discourse aspect	How it appears in TV crime shows
Setting	Crime scene or crime lab, one in squad room
Participants	Crime scene investigators, often subordinate and leader, police
Ends	Intended outcome is to communicate findings
Act sequence	Initiation, exposition, agreement or disagreement, closing response
Key	Tone varies; excited, serious, team banter, disbelief all possible
Instrumentalities	Speaking, sometimes viewing results onscreen
Norms of interaction	Usually polite turn-taking, occasional interruptions to complete each other's sentences
Genres	Respectful professional conversation

The grid in Table 5.4 shows that most aspects of the discourse in the transcribed parts of the shows were remarkably consistent between examples. Two settings predominated for a discussion of DNA: the crime scene itself, or the crime lab. Exceptions occurred in episodes of *Bones*[62] when Bones and Booth were in a car and were talking by videophone to their investigators in the lab. More extended discussions about DNA usually occurred between crime scene investigators; sometimes equal level colleagues, but more often subordinates reporting to leaders. Police sometimes mentioned DNA or called for such tests to be done, but rarely engaged in extended conversation about the technical aspects of the tests. The most variable aspect of the discourse was the Key; the situation and results of the tests brought about variations in the tone. That all other aspects were so similar, as seen in Table 5.4, indicated that crime shows follow a formula, which has been commercially successful, even though this formula may not reflect the reality of life as a crime scene investigator.

> **Comparative Assertion D: The discourse in three crime shows that frequently mention DNA (*Bones, NCIS,* and *CSI*) is very similar.**

Crime shows also depicted similar visuals, including a variety of samples and equipment associated with forensic and DNA work. Nine analysed excerpts yielded the

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data in Tables 5.5 and 5.6: three examples from each of *CSI*[63, 64, 65], *NCIS*[66, 67, 68], and *Bones*[62, 69, 70]. The *Law & Order: SVU* episode[71] was not included as in this excerpt the DNA results were discussed in the squad room, not the crime lab, but blood and saliva were the DNA sources used in this episode. Often, more than one DNA source is used, so Table 5.5 shows more than nine sources of DNA in the nine analysed excerpts.

Table 5.5

DNA sources seen in three excerpts from each of three crime shows (N = 9)

DNA source	*CSI*	*NCIS*	*Bones*	Total
Saliva (buccal swab for 2, from cigarette paper for 1)	1	1	2	4
Blood	1	1	1	3
Skin (trace DNA on touched objects)	1	2	0	3
Fingerprint	1	1	0	2
Semen	0	1	1	2
Tumour	0	0	1	1

Table 5.5 shows that four of the main sources of DNA seen in just this limited sample of crime show excerpts were saliva, blood, skin and fingerprints, as were the top four students' answers concerning the location of DNA as seen in Table 4.15 in Chapter 4. Students did not specifically mention *semen*; possible reasons for this omission might include not knowing the appropriate word to use for it, and embarrassment. It may have been included in their general answer of *excretions*, given by four students.

Comparative Assertion E: DNA samples shown in crime shows include saliva, blood, skin, and fingerprints; students named these as locations of DNA.

Table 5.6 enumerates the visual incidence of specific equipment in the nine excerpts, including only items seen in more than one show. Additionally, *CSI* scenes showed a gun, mannequin heads and splatter dye, bottled specimens, safety glasses, and details of fingerprint lifting film and inkpad and how to use them. Also visible in *CSI* scenes were molecular models (but not of DNA), a DNA analyser, and many tubes which went into an unexplained machine. *NCIS* scenes also showed a tilting test tube shaker, electrophoresis equipment, agarose gel slabs and the resultant blot, and a shoe print being analysed. *Bones*[70] showed a detailed picture of semen under phase contrast microscopy to show up the tails of the spermatozoa, used in a detailed explanation and linked to DNA results apparently indicating the suspect was of Asian descent.

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Table 5.6

Equipment associated with DNA as seen in three excerpts from each of three crime shows (N = 9)

Equipment associated with DNA	*CSI*	*NCIS*	*Bones*	Total
Reagents in bottles	2	2	2	6
Light microscope	1	2	2	5
Latex gloves	2	2	1	5
Lab coats	2	2	1	5
General lab glassware	1	2	2	5
Swabs for collecting buccal (salivary) DNA	1	1	2	4
Metal shelves	1	1	2	4
Display screen	1	1	2	4
Flashing results	2	1	1	4
Computer screen	1	1	1	3
Graph of DNA markers	1	1	1	3
Evidence bags	1	1	1	3
Powerful desk lights	2	0	1	3
DNA database	1	1	0	2
Forensic optical comparator (fingerprints)	1	1	0	2
Special light to show semen stains	1	0	1	2
Forceps/tweezers to handle evidence	1	0	1	2
Unexplained technical data	1	0	1	2
Crime scene photos	1	1	0	2

The results in Table 5.6 highlight the complex jumble of equipment visually associated with work concerning genes and DNA. Much of the equipment appeared highly technical, with many screens, arrays of controls, and buttons to press. Rarely was any of it explained in detail to the audience, giving two somewhat conflicting impressions to the viewer. One, that DNA work is very complex and difficult, such that all these complicated machines are required; and two, that the result appears with the push of a button, and usually just as the team leader needs it.

Comparative Assertion F: Considerable technical equipment is associated with DNA in crime shows.

Some TV shows were more accurate than others in showing the standards of cleanliness required for collecting and handling evidence in general, and DNA in particular. The use of latex gloves is now well established, or in emergencies, characters produced handkerchiefs from suit pockets and used these to handle a gun or other object. *CSI* erred in showing crime scene investigators working outdoors in street clothes and with free-flowing hair, presumably for the glamour aspect, especially for the women; *NCIS* was more accurate in sometimes showing them wearing cover suits and booties, with agent Ziva's long hair tucked up into a cap.

As shown in Table 5.6, the prevalence of the light microscope in the TV show laboratories parallel its use as a stock photo image in many newspaper articles about aspects of genetics (Media Assertion XII). This image is confusing, as genes and DNA cannot be directly observed through this instrument; only chromosomes, when prepared and stained. In one excerpt of *NCIS*[67], the forensic expert Abby looks through the microscope, but the high-powered objective lens is far too high above the specimen on the stage of the microscope to produce any viewable image. Twice as many students knew the microscopic size of DNA than could describe its shape (Genetics context Assertions 9 and 10); this may be due to the prevalence of the microscope in these DNA excerpts. The image of the shape of DNA was lacking from these TV show visuals; of all the media the students' viewed which could be examined and analysed, DNA as the double helix featured solely in advertisements where DNA was referenced in a symbolic rather than scientific manner. This fact may also account for the students' relative lack of knowledge of its shape.

Comparative Assertion G: The light microscope often features in television shows and newspaper articles in which DNA and genes are mentioned.

The *CSI* franchise is renowned for having state-of-the-art equipment, and an article in the *Enquirer* newspaper (Kiesewetter, 2003) reporting a tour of the *CSI: Miami* lab indicates that all the equipment is real. In 2003, the show's equipment included two $150,000 mass spectrometer machines, a $90,000 genetic analyser, and a real DNA analyser had just arrived, having been delayed as real crime labs were purchasing the machines as soon as they were made. However, the *Enquirer* article (Kiesewetter, 2003) reports that producers of the shows do not necessarily have to pay for the equipment; manufacturers are keen to lend them the latest gear so it will be noticed. All the machines work; but they do not work as fast as on TV. A DNA report is produced in

15 minutes, which would generally take at least 12 hours in real life. However, in October 2007 (Quilty-Harper, 2007), NEC produced the world's first portable DNA analyser that can do the whole five-step process from cell collection to results in just 25 minutes, so real life is catching up to TV time. This information means students are being exposed to real images of real equipment, and Bandura's (1977, 1994) social cognitive theory predicts that realism will enhance learning.

Comparative Assertion H: Real equipment is used on TV shows that depict the analysis of DNA.

Not all is entirely real; the *CSI: Miami* lab is actually in Los Angeles. The *Enquirer* (Kiesewetter, 2003) article closes by acknowledging the influence of *CSI*; not only have Las Vegas crime scene officers originally known as CSAs (Crime Scene Analysts) changed their name to CSIs, but they report that now when they go to crime scenes, members of the public know who they are and what they are there to do.

The pervasive nature of the term "CSI" is also demonstrated by it being the name of a UK company that markets crime scene investigation equipment, despite the British acronym being SOCO (Scene Of Crime Officer). Information on the *CSI Equipment* website (csiequipment.com, 2009) confirmed that many of the items depicted on shows such as *CSI* and *NCIS* are real and available for sale. However, some of the gadgets seen on the shows appear ahead of their time, such as the portable fingerprint machines that instantly transmit the prints back to the lab. It is possible that some equipment has been or will be developed for real use following its simulated appearance on such TV shows. Some gadgets are real, such as the luminol used on *CSI* to show up blood, but is not in as widespread use as implied by the TV show depictions. For example, luminol is not listed as essential in standard CSI kit lists such as that released from the National Institute of Justice [NIJ] (2009). Limitations of the use of luminol, such as also reacting to bleach, animal blood, and faecal matter, are not depicted on the TV shows, but are valid reasons for its more limited use at real crime scenes. The UK CSI company also markets an educational fingerprint kit suitable for students or "the young SOCO at home," indicating acceptance of the influence of television depictions of forensics upon children's interests.

Comparative Assertion I: The term "CSI" is pervasive and accepted by the public as referring to people who investigate crime forensically.

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Some TV shows acknowledge the influence they have on viewers' knowledge about crime scenes. In Series 2, Episode 6 of *The Mentalist*[72] opens at a crime scene. Detective Rigsby is there first and greets the arrival of the team leader, Lisbon, with a rueful look and the statement, "Local PD has stomped all over the scene so I don't think forensics will be much use." Lisbon looks disgusted and says, "Don't they watch TV? Even a toddler knows not to do that!" This particular TV show rarely mentions DNA as the focus is on the lead character's mental abilities to find out who is lying and solve the case. However, later in that episode, the statement "DNA doesn't lie" was made. Such a statement further reinforces to the viewer the absolute nature of DNA evidence, which is neither strictly scientifically accurate nor recognised as such by law.

Student viewing of crime shows and linking DNA to crime.

Having introduced the crime shows that frequently depict the use of DNA (*CSI, NCIS,* and *Bones*), the 62 students are now introduced in the context of their overall viewing of these crime shows, and their linking of DNA to crime. With a sample size of 62, the data are considered as a single Australian sample.

In terms of mass media influence, a possible interconnection was explored to see if viewing crime shows that frequently depict the use of DNA to solve crime leads to students linking DNA to solving crime. Four possibilities emerged. Students may be:

- viewers of crime shows who link DNA to solving crime,
- nonviewers of crime shows who do not link DNA to solving crime,
- nonviewers of crime shows who link DNA to solving crime, or
- viewers of crime shows who do not link DNA to solving crime.

Analysis of student responses placed the students in these four categories as shown in Table 5.7. Analysis also yielded explanations of how each group of students provides evidence that does or does not support interconnections between viewing crime shows and linking DNA to solving crime.

The first group of students in Table 5.7 consists of 32 students (51% of the total cohort) who are viewers and linkers. Some were regular viewers of *CSI, NCIS,* or *Bones;* others were occasional viewers. Although all year groups are represented, more of this group are Year 7 students, possibly indicating that older students may be more capable of deriving genetics information from the plots of crime-related TV shows. This group of viewers and linkers support the interconnection between the viewing of crime shows and students knowing about using DNA to solve crime.

Table 5.7

Comparison of students' viewing of crime shows and linking DNA to crime

Characteristics	Student information			Total
	Year 5 (*n* = 24)	Year 6 (*n* = 20)	Year 7 (*n* = 18)	(*N* = 62)
Group 1: viewers and linkers View *CSI, NCIS* or *Bones* AND links DNA with crime	**Joel**[a] **Katrina** **Tara** **Arunta** **Parri** *Tobias*[b] *Cory* *Cherilyn* *Tirranna*	**Skyla** **Aleeza** **Joey** **Hanja** **Diana** **Allirea** *Neil* *Brian* *Elvie* *Harlan* *Jacob*	**Branson** **Macey** **Shanee** **Annette** **Hailey** **Amberly** **Saul** **Burnu** *Bennett* *Tallulah* *Cherry* *Korra*	32
Group 2: nonviewers and nonlinkers Does not view *CSI, NCIS* or *Bones* (or any of the crime shows of interest) AND does not link DNA with crime	Carsten Adam	Cathleen Ian		4
Group 3: nonviewers but linkers Does not view *CSI, NCIS* or *Bones* (or any of the 7 crime shows of interest) BUT does link DNA with crime	Theresa Geraldine Benny Paul	Elaine Willis Prasai Anton Eliza	Madeleine Angela Connal Olin Kayley	14
Group 4: viewers but nonlinkers Views one or more of *CSI, NCIS* or *Bones* BUT does not link DNA with crime	**Anne** **Gia** **Coorain** **Coreen** **Alkira** *Tim* *Clarenne* *Lamilla* *Sharnie*	Katherine Jemilia	Geordana	12

Note: [a] **bold font denotes regular viewers (most episodes)**

Note: [b] *italics denotes occasional viewers (few episodes)*

The second group of four students, who are nonviewers and nonlinkers, also represent consistency with the interconnection between viewing crime shows and linking DNA to crime. These students cannot be expected to know what they have not been exposed to, that is, that DNA can be used to solve crime. Therefore, thus far, 36 students support the interconnection.

The third group in Table 5.7 are 14 students who do not watch *CSI, NCIS,* or *Bones,* and in fact, do not watch any of the seven crime shows of interest, but who did link DNA with solving crime. Superficially, this group of nonviewers but linkers appears not to support this interconnection of media influence. However, further analysis indicated two subgroups: one of 10 students and the other of 4 students. The first subgroup of 10 viewed other TV shows containing similar genetics concepts, such as *The Bill, Criminal Minds,* science shows, documentaries, *Home and Away,* and *The News.* Therefore, this subgroup of 10 students can be added to the 36 already shown to support the interconnection between exposure to crime shows and linking DNA to solving crime, making 46 students (74%) in total who support this interconnection. Within the second subgroup of four students, Prasai had learned about genes and DNA in school in Malaysia, and Kayley's self-paced learning allowed her interest in science to extend to high-level knowledge of genetics. Madeleine attributed her knowledge of DNA to TV (but no specific shows) and to overhearing parental conversations, and Angela had learned from her mother who was a nurse. These four students do not support the interconnection between crime shows and linking DNA to solving crime.

The last group in Table 5.7 consists of 12 students who view crime shows but did not relate DNA to solving crime. Nine of this group of 12 students are in Year 5. Genetics Assertion 2 indicated genetics knowledge increases significantly from Year 5 to Year 6, so these students may not be ready to, or are just beginning to acquire this knowledge. The existence of this group of viewers but nonlinkers does not support the interconnection linking viewing crime shows with knowledge of the use of DNA to solve crime.

> **Comparative Assertion J: Data from 74% of participating students support a connection between the viewing of crime-related TV shows and knowledge of the use of DNA to solve crime.**

Crime shows – detailed analysis.

To explore interconnections more deeply than in the foregoing general analysis, some examples of the 10 crime show transcripts are now presented with explanation, analysis, and comparison with students' excerpts. Descriptions of visuals and asides are in italics and each transcript and associated description is shaded.

Transcript 1:
Bones[69] Season 4, episode 4, *The Finger in the Nest*, 10 min 08 sec into episode:

Visuals: Booth (the FBI agent) and his son are playing ball in a park, and the son finds a human finger in a bird's nest. When the rest of the body is discovered at night, Dr Brennan aka Bones (the forensic anthropologist) and Booth go into the woods to find an opossum is chewing the body. Next morning, in the lab, Tam (the lab manager), Hodgins (a technician), and a new intern are reporting to Bones and Booth who are out in a car. The lab is very industrial, lots of metal surfaces, walls that look like roller-doors, grids, and grilles. Tam is wearing a business suit, Hodgins is wearing a hooded jacket, but the intern is in a grey lab coat with the famous da Vinci Vitruvian image on the pocket.

Tam: Dr Brennan, Hodgins found saliva.

Bones: Where?

Tam: On the victim.

Bones: Oh. Why was Hodgins looking for saliva?

Hodgins: I wasn't looking for saliva, I found it. Giant difference.

(Then follows some banter between the team about tone of communication and the interest only in results. Hodgins tends to be bad tempered).

Tam: Dr Hodgins was looking for particulates on the mandible and vertebrae that might lead to a murder weapon when he found saliva.

Hodgins: There was enough DNA in the wounds to run a DNA profile.

Booth: That was the possum right?

Intern: No, the puncture wounds indicate something larger.

Booth: Who was that? *(The intern is then introduced).*

Hodgins: I ran a standard 8 nuclear markers for *Canis.*

Booth: What is that, some kind of a bug?

Intern: Not a bug Agent Booth.

Hodgins: *Canis lupus familiaris (and an aside to the intern for interrupting).*

Booth is none the wiser, but Bones explains "Domestic dog."

Tam: Seth Elliott was killed by a dog with filed teeth.

Student statements are boxed and set out in a standard pattern: the student's pseudonym and details, and then their actual words. Further comments or information follows. Appendix D contains versions of student statements that are more complete. Compare Transcript 1 with the first student statement below:

Student Statement 1: Parri, Year 5 boy

I don't know much about DNA. I know police use it. I think DNA is dangerous, it kills people. I know on *Bones* they use DNA to find out who the murderer is.

Parri only scored 11/30 on the genetics knowledge interview, but correctly indicates that on *Bones* DNA is used to find the murderer, though in the case of this transcript, the murderer is a dog rather than a human. Parri also expresses a misconception that DNA kills people. He said his sole source of information was from TV crime shows. He watches *Cold Case* and *The Mentalist* regularly, but they rarely mention DNA. Therefore, his limited knowledge of DNA has most likely been derived from his weekly viewing of *Bones,* and as that always involves dead bodies, this misconception is understandable. Parri is one of nine students that mentioned *Bones* as a source of their knowledge.

In Transcript 1, the source of DNA used to identify the killer is saliva. Six students mentioned saliva as a location of DNA. Not all six mentioned it again when asked about DNA and crime, but Neil did so clearly.

Student Statement 2: Neil, Year 6 boy

If a criminal commits a crime, leaves a fingerprint or another DNA sample like blood, or spit, police can tell them apart from other people.

Neil watches several crime shows occasionally, including *Bones, CSI, The Mentalist, Law & Order*, and *Blue Heelers*, and reported learning about DNA from *The News* and *Find My Family*. Neil's comment refers to the more usual type of criminal, a person, and clearly indicates his understanding that DNA can be retrieved from forensic samples such as blood, fingerprints, and saliva (spit), to separate the criminal from others. One of the *NCIS* excerpts shows both saliva DNA and fingerprints being used to find a thief, in this case, the team member who stole a cupcake belonging to Abby (the forensic scientist). The fingerprint was not on the obvious location of the refrigerator door, but on the new box of latex gloves the thief had opened in an effort to leave no trace evidence of his crime. This light-hearted segment doubtless would not occur in a real lab, it being a waste of resources, but it is a segment likely to appeal to the age group in this research.

The second transcript is from *CSI*. The term "CSI" is now commonly used for three different things; the TV show, the crime lab, and the personnel who investigate crimes (as in CSI Sara). In Season 5 of *CSI*, Episodes 24 and 25 involved finding CSI Nick who had been kidnapped and buried alive. Nine minutes into Episode 25[64], Grissom (the team leader) delivers the ransom to Nick's unidentified captor who blows himself up, taking to his death the secret of Nick's location.

Transcript 2:
Visuals: CSI Sara locates the severed thumb of the captor at the crime scene and takes it back to the lab for testing. She is seen wiping it clean of blood, taking its fingerprint and running it through the computer for a match. No match is found, and she looks very disappointed. Cut to CSI Mia, the DNA technologist, appearing at Sara's door, looking excited and calling Sara (first words of transcript). Sara follows her and in the next shot, they are seen staring at a computer screen.

Mia (at Sara's door): Sara, I got something off your film! *(They relocate)*

Mia (sitting at her screen): So, when you struck out on prints, I ran DNA through CODIS (mispronounced as Calders) hoping the guy was in the system, from another case or a prior felony. No straight up match, but …

Cut to shot of screen headed "Standard ladder of alleles" with several column graphs, flashing red dots, chromosome numbers, XX and so on. Very technical in appearance and not in view for long. No suspect name on the screen.

Sara: … but you got a moderate string instant match for a Kelly Gordon?

Mia: Yep, 7 alleles in common, and based on age, I'd say it was his daughter.

Sara: Good work Mia.

Thus, they identify the culprit as the father of a woman still in jail for the crime for which her DNA was entered onto the database. They interview her, gaining a clue about her prior interest in horticulture, leading them to the plant nursery where Nick is buried, whereupon he is rescued in the nick of time.

This excerpt refers to two forensic techniques, conventional fingerprints, and *DNA fingerprinting*. As described in Lee and Tirnady (2003), this was the first name given to the creation of unique DNA profiles from DNA samples. The intent was to use fingerprints, with which many people were familiar, as an analogy for the accuracy of DNA sampling. This choice of analogy was questionable given that fingerprint identifications are not as reliable as people often believe, due to human assessment error. The choice of name also created an initial confusion that DNA itself was in the fingerprints, at the time this was not thought to be the case. A gradual switch to the term of *DNA* or *genetic profiling* in common use today (CrimTrac, 2011) occurred.

Eventually scientists found that fingerprints *do* contain DNA in sloughed dead cells, but an efficient process for extracting the very small amounts of DNA found in fingerprints was not developed and reported until 2003 (Choi, 2003). However, unless a scanning Kelvin probe is used (and this instrument is still being developed for this purpose as described in Williams, 2010), developing latent fingerprints at a crime scene destroys their potential for swabbing for DNA; similarly, swabbing for DNA destroys the distinctive characteristics of a fingerprint. Separate sampling is required, assuming there are enough fingerprints available. This episode did not show this fact visually nor explain it aurally, leaving the viewer to assume that both processes use one fingerprint. Three out of the four students who specifically mentioned *CSI* as a source of their knowledge also mentioned fingerprints.

In the same *NCIS* show as the cupcake incident, agent Ziva is shown tricking someone into signing a document in order to collect the pen used. It is not clear in this incident whether she wants the fingerprint for identification, or for DNA, but as she wraps the pen in a handkerchief, it is dubious as to whether either use would be feasible.

> **Comparative Assertion K: Crime shows do not distinguish clearly between fingerprints for identification, fingerprints as a DNA source and the process of DNA fingerprinting or profiling.**

In answer to the question about where DNA is located *in* the body, 14 of the 62 students said that DNA is in fingerprints, and a further 10 students linked fingerprints to DNA when asked about uses of DNA *outside* the body. Of these 24 students, only five did not record that they were regular watchers of at least some of the TV shows of interest on the questionnaire, and most of these students watched two or more of the crime shows regularly. Adam, a Year 5 boy, specifically stated that "DNA is in the lines on your fingers," Prasai, a Year 6 boy, said "Well, you can take fingerprints, that's a DNA sample," and several students spelled out that no two people have the same fingerprints. However, two students knew that even identical twins do not have identical fingerprints, though could offer no scientific explanation as to why this was the case. Science now recognizes that these statements are accurate, but that they constitute a one-sided, crime-oriented view of DNA, given that so few students knew that DNA is located in all cells, and has important biological functions. Following are more examples of specific excerpts from the students regarding DNA and fingerprints.

Student Statement 3: Arunta, Year 5 boy:

DNA has to do with blood types and fingerprints, it helps to identify us. It can find out criminals and relatives. I learned about DNA on *Law & Order* and *Cold Case*.

In his questionnaire, Arunta also reported regularly watching *NCIS, Without a Trace*, and *The Mentalist*. The interview process resulted in learning, as initially he could not name the genetic factors responsible for inheritance. However, he did claim to have heard of DNA and, as stated, related DNA to finding criminals and relatives. He then came to his own realisation that the genetic factors must be DNA. In an interesting twist, his twin sister Alkira reported watching all the same TV shows to the same degree of regularity, yet did not know as much about DNA, and could offer no ideas as to how it may be used. She did not know the name of the genetic factors and did not arrive at the same realisation as her brother. The results for these twins indicate that social learning does not always have the same degree of influence, and that other factors may determine how much a student learns.

Student Statement 4: Saul, Year 7 boy:

Everyone has different DNA, it tells who you are. We use it to find out who you are. Like we can do DNA fingerprints to solve crime.

Saul specifically used the term *DNA fingerprints* in his statement. Fingerprints were also the first location that he suggested for DNA, so this may indicate his awareness that DNA is extractable from that source. Other locations he mentioned were the usual forensic sample areas, although he also said DNA would be in peoples' eyes. Saul said, "I don't really pay attention to TV though, it depends on what it is," although in his questionnaire he reported watching *NCIS* and *Bones* regularly, *CSI* occasionally, and one of his three favourite shows was *The Simpsons*. Saul also mentioned seeing experiments involving cloning the woolly mammoth using elephant eggs on a documentary. This was probably "*Raising the Mammoth*"[73] shown on Discovery Channel; these experiments have not yet succeeded. He also mentioned work in China involving putting human DNA into robots, which has been accomplished at the nano scale. Again, he attributed his knowledge to a documentary, but no such documentary was found to have screened in Australia. However, the Chinese work was the subject of news broadcasts and a YouTube clip[74], so either of these may have been the source of his knowledge. It is obvious that Saul's specific knowledge about these uses of DNA

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has arisen from the mass media; presumably, this information was sufficiently attention grabbing for him to learn and remember in detail.

Crime shows may not be the sole source of information about genes and DNA for students; however, they may provide subsidiary information.

Student Statement 5: Joel, Year 5 boy:

If someone broke into a car, you can put a special powder over it, it shows up the fingerprints, then you get the DNA. I know because my Auntie's car was fingerprinted. And I've seen it before on *CSI.*

It is possible in this case, that having seen the process of extracting DNA from fingerprints before on TV made Joel more interested and aware of what was happening to his Auntie's car.

Analysis showed that if participants watched other TV shows, but not crime shows such as *CSI, NCIS,* or *Bones*, the information provided in the interview about using DNA to solve crime tended to be less detailed, as shown by Anton's statement.

Student Statement 6: Anton, Year 6 boy:

Skin, hair, blood samples and fingerprints contain DNA ... can use it to solve crime. They use DNA for forensics. But is there dead DNA? I'm not sure what happens to DNA when they die. DNA keeps us alive.

Anton did not record watching any of the TV shows of interest (crime and family relationship shows) but *The Simpsons* and *Futurama* were favourites, both of which have genetics content. His comments and excellent question about dead DNA show that some of these young students are remarkably thoughtful about genetics content considered by curriculum designers to be too difficult or unsuitable for them.

The six statements presented above are all from boys. Some girls linked fingerprints and DNA, but even if they were regular viewers of crime shows or chose them as favourites, the girls' answers tended to be less descriptive than the boys' answers.

Student Statement 7: Tallulah, Year 7 girl:

Can use it (DNA) to solve crime if there's fingerprints on stuff.

Tallulah's favourite TV shows included *Home and Away*, and *Criminal Minds*, both of which sometimes mention DNA. She also reported being an occasional viewer of *CSI, NCIS, Bones*, and *Law & Order*.

> **Comparative Assertion L: 38% of participating students linked fingerprints to DNA but most did not distinguish clearly between using fingerprints for direct identification, fingerprints as a DNA source and the process of DNA fingerprinting/profiling.**

Only a few students made the distinction between where DNA is located in the body, in all cells, and where we look for it to obtain samples.

> **Student Statement 8:** Korra, Year 7 girl:
>
> We can look for DNA in hair and fingerprints but it's in all cells. I found out about DNA from TV shows, crime shows, not the *News* or from ads.

One of Korra's favourite shows is *Home and Away*, and she reported being an occasional viewer of *CSI, Bones,* and *Cold Case*.

Transcript 2 from *CSI*[64] also identifies the practice of *familial searching* using DNA. From the body of *CSI effect* research as described in Chapter 1, it is known that few members of the general public realize that a person's entire DNA (more correctly termed their *genome*) is not used for DNA matching. In fact, only a few sections of DNA (10-13 depending on jurisdiction) are sampled for matching, sections known as *Short Tandem Repeats (STRs)* (Lee & Tirnady, 2003). These STRs are considered sufficiently robust to survive degradation, suitable for amplification processes needed to conduct the test, and, as each person has two alleles for each STR, 13 STRs can create a unique genetic profile for each individual. Familial searching will find less direct matches between these STRs as family members have unique, although similar DNA. In this *CSI* episode's case[64], the match was apparently with "seven out of the 13 alleles." Seringhaus (2009) points to some problems here. Firstly, there are 26 alleles to consider, not 13. Secondly, CODIS does not usually generate partial matches with so few alleles; special software is needed for familial searching. Many partial matches are generated which require sifting based on other factors such as location and age. Finally, the partial match would have to be confirmed by an exact match with the suspect's own DNA. None of this was explained in *CSI*, neither was the technical terminology such as

what an allele is, and, as is typical, time was compressed between the taking of the fingerprint and the results of the DNA scan. CSI Sara also appeared to be psychic in knowing the name of the suspect as it was not shown on the technical screen amongst the flashing results.

> **Comparative Assertion M: Crime shows do not explain that only some parts of a person's genome is assessed, or the technical details of the process, but do indicate the type of information that can be derived from DNA profiling.**

However, technical information is not always scientifically accurate. In Transcript 1 from *Bones*, a "standard 8 nuclear markers" was mentioned, leading to the identification that a dog was responsible. There is no such thing as "standard 8" markers. Similarly, also in *Bones*, mention is made of "42 DNA sequences" to ascertain from semen that a suspect is of Asian descent. Such an analysis would be highly unlikely, at best.

However, that students (both girls and boys) acquire some knowledge of the overall process is indicated by the following three student statements:

> **Student Statement 9:** Shanee, Year 7 girl:
>
> If criminals leave a hair sample, we can computer match their DNA. Police put DNA records onto a computer. I learned about DNA mostly on *Bones* and *NCIS*, not so much on *The Mentalist* and not much on the *News*.

Shanee listed *Bones* and *The Mentalist* as her favourite shows, and she reported being a weekly viewer of *NCIS* as well. She is also well aware of the degree to which DNA is mentioned in the different TV shows, correctly identifying that it is mentioned more often on *Bones* and *NCIS* than on *The Mentalist.*

> **Student Statement 10:** Willis, Year 6 boy:
>
> Also, if there's a criminal, a crime scene, they can . . . a tiny hair follicle you know can be looked at under the microscope and they can find all the DNA. For crimes they like . . . if you left like your hat, there's pretty much a 99% chance that there's going to be like hair or skin cells or sweat that they can use to find the DNA. Then . . . well if it's a criminal who did it, they'll probably log it into the computer and then the computer will come up with all these subjects and the DNA will give you maybe one or two people who might have a direct match.

The only crime show Willis views is *The Bill*, on which DNA is relatively rarely mentioned compared with its prevalence on shows such as *CSI, NCIS*, and *Bones*. His precise knowledge about its use is possibly due to his having researched the topic himself on the Internet, as he explained at length in his interview.

Student Statement 11: Annette, Year 7 girl:

DNA can also be used for like tracking a criminal, like, for example, there's bits of hair left on . . . or something they tried to steal or something . . . 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. I learned from my parents, like if I watched a certain TV show and it might have spoken about some things I don't understand, like genes, or something, I might have asked them and they explained it all to me. Usually the later night shows, on *NCIS*, and *Law & Order* a little bit. Oh and I've heard about it on the *News* too, when I was younger.

Annette's favourite show overall is *The Simpsons*, and she reported watching *NCIS* and *Law & Order* weekly, and *CSI* occasionally. Annette was very knowledgeable, and was rare in mentioning that she and her parents discuss genetics topics from TV.

Shanee, Willis, and Annette all scored well on the interview, and were the only students who explained that DNA information needed to be already stored in the computer in order to make a match. Willis and Shanee clearly understood that only criminals would already have their DNA information stored, whereas Annette was less specific in her answer. Other students mentioned scanning DNA in various ways, for example, Olin, a Year 7 boy, said, "Can find parents by scanning DNA to compare and find them." A more typical answer involving crime was that given by Macey, who did not specify that the information needed to be in the database.

Student Statement 12: Macey, Year 7 boy:

Can use DNA to catch the criminal. Use a special white powder on the fingerprints or blood, and then they do a process in a machine or something, and find the person. On cop shows, *NCIS, Bones* and the *News*. I like Abby on *NCIS*.

Macey's favourite show is *The Simpsons*, he "loves *The Mentalist*," regularly watches *NCIS* and *Bones*, and occasionally views *CSI, Without a Trace,* and *Cold Case.* The use

of fingerprint powder was seen in detail in two of the sampled excerpts, one from *CSI,* and the other from *NCIS.* As seen in Table 5.6, two of the excerpts detailed the use of DNA databases, though others showed computers, screens, flashing results and other machines. Given this was a small sample of nine excerpts, the prevalence of DNA databases and computers suggests it is not surprising that some students were familiar with this equipment.

In all, 10 of the 62 participants related DNA to databases, scans, computers or machines, and all but one of them watched at least one (more usually two or three, and up to seven) of the TV crime shows of interest. Six of the 10 students also listed as favourites other TV shows known to contain similar genetics content as described in Chapter 4. One listed *The News* and another listed *Sunrise* (an early morning news and chat show) as favourites, and these shows sometimes mention DNA. The only one of the 10 students with no reported exposure to genetics-containing media was Prasai, who, as noted previously, gained his considerable knowledge of DNA and genes from his previous school in Malaysia and his own research. These 10 students were all from the higher SES areas (Samples 1 and 2). Student responses became noticeably shorter and less detailed as SES declined, so although some students in Samples 3 and 4 knew of DNA's use to solve crime, they offered fewer details about how this works.

> **Comparative Assertion N: 14.5% of participating students were aware that DNA could be matched by machines and were also viewers of crime shows and other TV shows known to contain genetics content.**

The most common misconception expressed by participants was that DNA is limited to being found in blood, or blood and other body parts subjected to forensic analysis. Again, the issue is not that DNA is *not* found in these body parts, it *is*, but in the belief that it is *limited* to these parts. One *CSI* excerpt graphically made the point that DNA is in blood, as blood spatter patterns from two victims were analysed, and only one type of DNA was found. CSI Grissom (the team leader) conducts tests using mannequin heads filled with dye and concludes that the victims were identical twins tied back to back and shot through their heads, hence only one type of DNA was found in the blood analysed by CSI Sara. As seen in Table 5.5, crime shows rarely mention DNA in any other context than taking a sample of saliva, blood, skin (and trace DNA), fingerprint, or semen. Consider this excerpt from Series 6, episode 4 of *NCIS*[67].

The plot implies that the victim was the probable father of a young boy born to the daughter of a public figurehead in the town. She denies having ever slept with the

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victim even though they had been close friends before the victim enlisted in the marines. In a twist, it is revealed that the actual father/son connection was that the victim was the illegitimate son of that public figure, so a potentially incestuous union could have occurred had he returned and developed a relationship with the daughter. The victim could also lay claim to inheriting the property and so he was killed.

Transcript 3[67] shows how often DNA is typically mentioned in an episode when it forms part of the evidence required to solve the crime. Also typical is the absence of the word *gene*, the closest being *genetically inherited*. Although efforts are made to create a sense of realism, Abby specifically mentions a centrifuge but there was not one in shot, whereas the tilting test tube shaker shown was probably unnecessary. This convoluted plotline links DNA with being essential evidence, the modern thing to use, and with DNA being shed on everyday objects upon which it remains despite them being discarded. The plot outlines the law for collecting DNA without specific permission. DNA is also linked with blood, blood types, microscopes, white lab coats, mysterious equipment, and coloured dots on a gel, in which an inherited blood anomaly can apparently be seen. This equipment is used to unravel complex family relationships, which not only identifies the victim, but also the criminal.

A remarkably similar plotline occurred in a double episode of *Bones*[62], screened around the same time, and set in England, although all the forensic work occurred in the USA. This unlikely scenario featured a real disorder, Von Hippel Lindau disease (VHL). With insufficient foetal blood available, DNA was sourced from tumours (typical of VHL) in the young pregnant female victim. The victim's mother had died years ago with no record of VHL, so lead character Bones surmised that the victim's biological father must have the disease and passed it on to the victim. No explanation of the inheritance pattern of the VHL mutation, traditionally described as *autosomal dominant* was given to support this assumption. The apparent father of the victim was "healthy as an ox" whereas the victim's boyfriend's aristocratic father used a walking stick, and his paternal grandmother was in a wheelchair. Based on that "familial evidence," Bones surmised that the boyfriend's father must also have been the victim's biological father, and that she had been killed (by the butler) to prevent an incestuous relationship. Yet gait disturbances occur in only some VHL sufferers, as symptoms are related to the precise location of angiomas and tumours, so this was an assumption based, at best, on minimal evidence.

> **Comparative Assertion O: TV show plotlines reinforce links between DNA, blood, crimes, criminals, victims, and sometimes also disease and family relationships.**

In all, 25 of the 62 students (40%) specifically mentioned using DNA to find "who did it," with nine using the word *criminal*, and others referenced *suspects, escapees, thieves,* and *murderers*. In the following statements, Theresa and Cherry were from Samples 1 and 2, whereas the two boys, Paul and Jacob, provide examples of more detailed answers than were typical from the lower SES Sample 3.

> **Student Statement 13:** Theresa, Year 5 girl:
>
> DNA looks like a white fluid; I've seen it on TV. I can't remember more, but I know it's white. I'm really interested in medical shows and crime shows, though I don't watch those listed, I watch others. I know they use DNA to find out who the criminal is and keep them in jail so nothing else bad will happen.

Theresa refers to criminals and keeping them in jail, attesting indirectly to the use of DNA as evidence. Her favourite TV show is *The Simpsons*; she did not name specific crime shows that she does watch in the interview.

Cherry makes a more direct reference to using DNA as evidence, and testing suspects, whereas Paul refers to DNA being found and used to track objects.

> **Student Statement 14:** Cherry, Year 7 girl:
>
> DNA is your blood in you; there's different groups of DNA. I learned about DNA on Doctor shows like *Grey's Anatomy*, on *Bones* and other crime shows. And a bit from the *News*. We can donate DNA blood to people. We can use DNA as evidence if someone's been stabbed. We can run tests on suspects.

Cherry references both medical and crime shows, and specifically refers to evidence in stabbing cases, an indirect link to blood, though she answered that DNA is found *everywhere*. Paul specifically references DNA being in fingerprints, and it being found on guns. Paul said he watches science shows and crime shows, though did not report watching any of the crime shows in the TV shows of interest list. However, he did report watching *Can We Help?* although that would be an unlikely source of these ideas. Jacob was the only student to express clearly the idea that DNA could be used to exonerate people as well as to identify them. Jacob reported occasionally viewing *CSI, NCIS, Bones, Without a Trace*, and *Law & Order*.

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Student Statement 15: Paul, Year 5 boy:

Can use DNA to track soldiers who died in Gallipoli to see who they're related to. It's (DNA) in your fingerprints to solve crime, to track guns or weapons.

Student Statement 16: Jacob, Year 6 boy:

Can use DNA to see if you were at a crime scene . . . or not.

Comparative Assertion P: 40% of participating students linked DNA to criminals and evidence in ways similar to that portrayed in crime shows.

In Student Statement 14, Cherry expressed a link between watching medical shows, and believing that DNA *is* blood that can be donated. This statement prompted a check of the 15 students who mentioned medical and health sources of their information about DNA. Within this group of 15, 11 thought DNA was in the blood, and seven of those thought it was *only* in blood. Eight of the 15 linked DNA to disease, and three clearly said that DNA *was* blood, and could be donated. These numbers are proportionately higher than those with similar beliefs in the remaining 47 students. For example, 19 out of 47 thought DNA was in the blood but just three of them thought it was only in blood. Only 11 of the 47 linked DNA with disease, and three thought that DNA was blood and could be donated, these students named school science lessons, science shows, and science magazines as sources of their information about DNA. From these data, it appears that exposure to medical shows and other health-related sources may lead to students acquiring strong mental links between DNA and blood.

Comparative Assertion Q: Viewing medical shows and other health-related sources of information may result in students closely associating DNA with blood.

In all, 15 of the 62 students explained that DNA could be used to identify the dead, those who were murdered, or the victims of crime. Students linked DNA with either the criminal or the victim; Kayley, a Year 7 student from Sample 3, was the only student to connect DNA with identifying both the criminal and the victim. She was quite knowledgeable, achieving the second highest interview score of 27/30 and was by far the most knowledgeable from her area (Sample 3), due to her interest in genetics developed through self-paced study.

Student Statement 17: Kayley, Year 7 girl:

We can use DNA to track down the person who was the victim as well as the criminal. DNA is a big long name for a type of acid that makes up the genes. It's what tells your body how to grow. Chromosomes are in each cell – there are 46 in each cell, but 23 in a reproductive cell, so when two join, you get 46 again. DNA can be used to diagnose disease. Can also use bones for forensics, and can use DNA to tell who the father of a baby is.

However, Kayley did not list any favourite TV shows, nor reported watching any of the TV shows of interest. She had more biological knowledge and less specific knowledge about DNA's uses outside the body, possibly encountered from reading books.

As shown, several students offered answers that encapsulated some ideas about DNA, blood, fingerprints, crime, families and disease; but one student, Diana, linked *all* these ideas from the *NCIS* and *Bones* plots together in her answers.

Student Statement 18: Diana, Year 6 girl:

DNA is blood. Genes is a part of you, DNA is your uniqueness inside you. DNA is your blood type. You can be identified by your DNA and your fingerprints, no one's is the same as each other. You can use DNA to tell if you've got a disease. And you can take blood from them and the possible father and look for similarities. If there's a robbery, can get fingerprints, that's DNA, and put them in the computer and find out who it is. Or blood would work as well.

Diana related DNA to blood, believing erroneously that it is the blood type, and related DNA to fingerprints. She knew that the answer would be found by putting the DNA (as blood or fingerprints) into a computer. One of Diana's favourite TV shows is *The Simpsons*; she also reported being a weekly viewer of *NCIS*, a regular viewer of *Law & Order*, and an occasional viewer of *CSI* and *Bones*.

Crime shows also show DNA being collected from trace evidence; objects touched by the criminal, such as crockery, cutlery, pens, or, in one of the analysed excerpts from *Bones*[70], on saliva on cigarette paper used to make marijuana joints. Some students were also aware that trace evidence might have DNA, with the clearest statement made by Cherilyn, a Year 5 girl from Sample 2.

Student Statement 19: Cherilyn, Year 5 girl:

Everyone's DNA, apart from your family, is different. DNA is in blood, fingerprints, it circulates through your body. Also, DNA - if you've touched a glass they can look at your fingerprints and say who it was. On *Bones* they use fingerprints to tell who that person is if they don't know.

Cherilyn reported being an occasional viewer of *CSI, NCIS*, and *Bones*. Throughout the interview, she expressed strong beliefs that DNA is in blood and in fingerprints.

Most of the excerpts expressed great confidence in the ability to obtain DNA from samples (for example, "I *can* get DNA" from the stub of the marijuana joint), where that certainty is not always justified. Similarly, usually one obvious and correct match is produced from their DNA tests. Only one excerpt from *CSI* raised any problem with DNA testing, an issue of contamination, said to be from the manufacturer (of what, was unclear). In this case, the contamination meant that all DNA tests from the last 48 hours would have to be repeated. The potential problem of insufficient DNA in the samples to accomplish that was not raised. However, a more serious issue of deliberate DNA fabrication was raised in the excerpt from *Law & Order: SVU*.

The excerpt analysed was in Series 11, episode 9 of *Law & Order: SVU*[71]. In this case, Detective Olivia Benson was framed for a murder, as her DNA was apparently in the blood on the murder weapon, a knife. As well as explaining that DNA was retrievable from such items, technical terms such as the unusual absence of methylation of DNA markers and research conducted in Israel about the fabrication of DNA evidence were mentioned. The TV show explained the fabrication process involves spinning off the white blood cells containing the original blood donor's DNA, amplifying salivary DNA from the person to be framed, and mixing the salivary DNA with the now DNA-free blood. Ironically, this method is detectable with TV's ubiquitous light microscope, as viewing the fabricated blood sample would show a curious absence of white blood cells. However, as evidenced by the FBI's published standards for DNA testing (2009), DNA testing laboratories did not routinely view blood under a microscope before testing. This explanation precisely matches reports of the work of real scientists in Israel, the main thrust of their research being the test they have developed to distinguish such fabricated DNA from a genuine sample based on the degree of methylation (Frumkin, Wasserstrom, Davidson, & Grafit, 2009). In this episode of *Law & Order: SVU*[71] a character says, "It's so easy, any biology undergraduate can do it," echoing the statement of the lead author,

Dan Frumkin, "Any biology undergraduate could perform this" as reported in the mass media (Pollack, 2009; *CBS News*, 18 August, 2009).

The mass media itself is aware of the rapid movement of scientific advances into TV crime shows, as indicated by a *CBS* report of Frumkin et al.'s (2009) research (18 August, 2009). This report states, "As the paper's author says, 'You can now just engineer a crime scene.' Good news for crime dramas on television but not so much to [*sic*] the criminal justice system." The *Law & Order: SVU*[71] episode aired just three months after these news reports, during the data collection phase of this research. Nine students were regular viewers of the *Law & Order* group of shows, but the student who specifically regularly viewed *SVU* was interviewed prior to this episode going to air. It will be interesting to observe how much impact this development has on DNA evidence, and whether students in future interviews will mention DNA fabrication.

Collectively, the data presented in this section, including qualitative data about students' viewing of the TV crime shows of interest and the commonality of concepts and themes between the mass media and the students' knowledge, lend credence to the idea that the nature of the genetics content to which they are exposed influences what they know about genetics.

Family relationships shows.

Another common theme as revealed by analysis of genetics-containing media in Chapter 4, and found in students' expressed understandings, is the connection of genes and DNA to family relationships. This link is addressed in some crime shows, as seen in the transcripts supplied, and three of the 10 TV shows of interest: *Find My Family, Can We Help?* and *Who Do You Think You Are?* The latter show's rather dry style involving mainly documentary evidence appears not to have appealed to the student participants in this research, with only five students having ever watched it. *Who Do You Think You Are?* does not mention DNA.

However, 35 (56%) of the participants reported watching *Find My Family,* half doing so regularly. Unfortunately, this show was cancelled during the data collection phase of this research. Episodes were removed from the Internet, preventing detailed examination of the contents. Notes made during live-to-air screenings indicate that many episodes referred in nonspecific ways to inheritance and genetics. Comments such as "the MacGregor nose," "she looks a bit like me and a bit like my Mum," and "you ARE your grandmother" occurred in most episodes watched. There were also many

comments about blood and bloodline, equating inheritance (and hence genes and DNA), with blood. Eight of the 17 students who watched it regularly expressed strong associations of DNA with blood.

> **Comparative Assertion R: The family relationship show *Find My Family* links inheritance (and hence genes and DNA) with blood, as do half of the regular viewers of this TV show.**

Some episodes of *Find My Family* featured people such as Tanya (Series 2, episode 1) with a genetic condition (haemochromatosis, a blood disorder, in her case), who are desperate to trace their lost children to warn them. Those episodes were more explicit about the genetic condition, its incidence, and risks. Two episodes dealt with twins, and two dealt with doubt expressed about the authenticity of the discovered relationship and the use of science (DNA tests) to decide.

Regular viewers of *Find My Family* included students who knew very little else about genes and DNA, but knew that it could be used to resolve paternity or to find lost family members. The clearest statement was made by Cherilyn, a regular viewer of *Find My Family* and an occasional viewer of *Who Do You Think You Are?*

> **Student Statement 20:** Cherilyn, Year 5 girl:
>
> Can do a DNA test so if your blood matches to your parents, that means you're related but if they don't, you might have been adopted. DNA can be the same as others in your family but different from everyone else. Can use DNA to prove whose family you're in if we ever need to know, if we don't know.

In addition, Sharnie and Tirranna, both Year 5 girls from Sample 4, said, "DNA can tell whose Daddy is whose," and "Can use DNA to find out who's the Daddy." Similarly, Coreen, a Year 5 girl from Sample 3, knew little else about DNA but knew "A DNA test will show who you're related to." However, viewing such a show does not guarantee that students will acquire specific ideas about DNA with respect to families; about half the students who reported watching *Find My Family* did not make specific statements about DNA's use to trace family relationships.

Can We Help? was watched by seven students, with the family relationship segment, *Lost and Found*, occurring in 133 of the 211 episodes. This show was cancelled in June 2011, rendering live episodes unavailable, but transcripts of all

episodes remained available online as of November 2011[75]. The *Lost and Found* segments focused on family resemblance, in both physical features and behaviours. A specific example was shared musical talents seen as having a genetic basis (episode 16 of 2010[75]). Many episodes spoke of blood, especially blood relatives. However, the distinction between being a biological parent and a nurturing parent was also made in some episodes, usually affirming the role of the adoptive parent, such as this statement from Carol, the biological mother, in episode 20 of 2010[75]: "I'm scared, I'm excited. I can't call her my daughter, even though she's my blood, she's their daughter."

Relatively few episodes mentioned DNA specifically, with most family links established through documentary evidence. In episode 32 of 2007[75], DNA testing confirmed that three siblings all had the same mother. In episode 7 of 2009[75], a need for DNA tests to confirm the relationship between two brothers was expressed. The tests were explained accurately, as was the need to wait one week for results. The following week, the DNA test results showed it was highly likely they were brothers. Specifically, the results reported that they ". . . are 117 times more likely to be related as half biological siblings compared to unrelated individuals[75]." Appropriately, the word *proof* was not used. The brothers were followed up a year later in episode 11 of 2010[75], and the DNA test to confirm the brotherly relationship was mentioned.

The foregoing analysis shows that DNA was not often specifically mentioned in *Can We Help?*, yet Willis, a Year 6 boy, not only named the show as a favourite, but also specifically mentioned it in his interview, saying "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." Similarly, as noted previously, Olin, a Year 7 boy stated that "You can find parents by screening DNA to compare and find them," and Paul, a Year 5 boy, was one of three who also mentioned identifying unknown soldiers, saying, "Can use DNA to track soldiers who died in Gallipoli to see who they're related to." Both Olin and Paul watched *Can We Help?* as did Tara, a Year 5 girl, who knew that "DNA can find out who's the father."

> **Comparative Assertion S: Viewers of family relationship shows linked DNA with paternity and the capacity to identify people to resolve family relationships.**

Can We Help?[75] had other general interest segments, and DNA was featured in at least two of those (from the online summaries). In both segments, the science was explained carefully and accurately. One segment investigated GM flowers, involving

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proteins, RNA, and genes. The second segment explained how a person's DNA could appear at a crime scene in which the person was not involved due to a recent whole blood transfusion, citing one case in the UK in the 1990s. From the media research conducted for this study, this episode[75] was a rare example of a cogent TV explanation that DNA is contained in the nucleus of cells, specifically white blood cells. The scientific accuracy and clear explanations about DNA offered in *Can We Help?* may help explain why Willis, the only student to list this TV show as a favourite, was so knowledgeable, earning the equal top score for genetics knowledge on the interview.

Summing up the cross-comparative data presented in this section, it is evident that many of the students' statements echo what they have seen and heard in TV crime shows and family relationship shows. Many presented statements provide details, particularly about solving crime, that are hard to explain as having come from other sources. Some elements of the mass media acknowledge the influence that such shows have on their audiences.

Although it is true of the majority (74% of these participants as seen in Table 5.7), there is no one-to-one correlation between viewing the crime and family shows of interest and having particular knowledge. Some students watch such television shows and do not make statements that resemble the ideas to which they have been exposed, and others have knowledge that appears to have come from types of shows they do not report watching. The true situation is clearly complex, requiring much finer grained data collection and analysis to be more confident of interconnections and relationships.

Connections Between Students' Viewing, Knowledge and Motivations

The main emphases in the mass media questionnaire were how much and to what mass media the students are exposed. However, questions about their favourite choices, whether they liked or disliked the 10 TV shows of interest, and favourite characters from those shows were included to yield data about their motivations for viewing.

Group 4 (viewers but nonlinkers) in Table 5.7 was a group of students who viewed crime shows but who did not link DNA with solving crime. Group 4 students had the least genetics knowledge as revealed by their interviews, and most (9) were in Year 5. This finding indicates that for some reason, these students were not actively acquiring genetics information from the TV crime shows they view. With fast-moving plots, action, and bantering between characters, particularly in shows such as *NCIS* and *Bones*, crime shows offer many possibilities for pleasurable viewing without dealing with the

intricacies of the scientific nature of evidence. Five members of Group 4 nominated at least one crime show as a favourite; these five students are shown in the left column of Table 5.8. Seven other interviewed students also nominated crime shows as favourites, and they are shown in the right column of Table 5.8.

Table 5.8

TV crime shows nominated as favourites by interviewed students

TV crime shows	Students nominating show as a favourite	
	Did not link DNA to crime	Linked DNA to crime
NCIS and/or *NCIS: Los Angeles*	Gia (Yr 5) *NCIS*	Skyla (Yr 6) both shows Hanja (Yr 6) *NCIS*
Bones	Clarenne (Yr 5) Coorain (Yr 5)	Shanee (Yr 7) Hailey (Yr 7)
Law & Order	Jemilia (Yr 6)	
The Mentalist		Shanee (Yr 7)
Cold Case	Jemilia (Yr 6)	
Criminal Minds	Coorain (Yr 5)	Tallulah (Yr 7) Burnu (Yr 7)
George Gently	Katherine (Yr 6)	
The Bill		Willis (Yr 6)

Table 5.8 indicates that crime shows are sufficiently popular to be a favourite show of 19% of the interviewed students. Table 5.8 also shows that older students in Year 7 linked DNA with solving crime, whereas younger students did not. This may indicate different motivations for viewing and enjoying crime shows, and may link with the significant increase in genetics knowledge previously noted from Year 5 to Year 7 (Figure 4.15). Although 15 students recorded "liking" *CSI*, none nominated it as a favourite.

Students nominating a show as a favourite presumably watch it regularly because they enjoy it and are motivated to watch it; therefore, the responses of this new group of "12 crime show fans" were explored further. Table 5.9 brings together the genetics knowledge of the 12 crime show fans with their perceived sources of genetics information. Knowledge is first represented by their overall scores on the interview, and used to rank the students in order. However, as seen in the previous descriptions, crime

shows mostly depict external uses of DNA so the scores on this section of the interview are separated out, with a maximum possible score of three, as is their specific response to the question about DNA and crime. These scores are cross-tabulated with the numbers and types of sources of genetics information mentioned by these 12 students.

Table 5.9

Breakdown of interview scores and responses of the 12 crime show fans

Student	Total Interview score (/30)	Uses of DNA score (/3)	Is DNA used to solve crime?	Number of sources of information	Main source stated
Willis	28	3	Yes – database match	3	TV
Shanee	24	3	Yes – database match	3	TV
Hanja	24	3	Yes – match it	3	TV
Katherine	21	2	Forensics (not crime)	2	TV
Hailey	20	2	Yes – ID victim	5	TV
Skyla	19	2	Yes – fingerprint, hair	3	TV
Tallulah	18	3	Yes – fingerprints	1	TV
Burnu	17	3	Yes – no details	1	Newspaper
Jemilia	15	0	No	3	Parents
Clarenne	12	1	No definitely not	2	Parents, Dr
Gia	7	1	No	None	
Coorain	6	0	No	None	

The bottom four students in Table 5.9 are crime show fans who do not know that DNA is used to solve crime. Clarenne is unique in saying it definitely cannot be used for this purpose. The four students generally mentioned fewer sources of their genetics information and placed less emphasis on TV as a source of their genetics information.

The top eight students in Table 5.9 are quite different from the bottom group of four in terms of their knowledge about external uses of DNA, and in the number and types of sources of their genetics information. The top eight crime show fans indicate a progression of knowledge, from specific answers about computer databases from the top two students, to more general responses about using hair and fingerprints. Katherine, the fifth student to nominate a crime show favourite but not mention DNA's use for solving crime, did mention forensics, in terms of scientists working with blood and genes to determine unknown relationships, not necessarily related to crime.

Jemilia is an interesting case as she is a particularly heavy viewer of crime shows, regularly watching *NCIS, Bones, Without a Trace, Cold Case, Law & Order, Find My Family,* and *CSI* occasionally. *NCIS* and *Law & Order* are not available free to air where she lives, but her parents buy DVDs of these two popular shows. Jemilia said her Dad told her that DNA is passed through the bloodline, and although she thinks DNA is only in the blood, she mentioned that it is passed through mother's milk. Jemilia mentioned school as a source of genetics information but only in the context of discussing this research project. When probed about learning about DNA on TV, Jemilia said "maybe, a long time ago." She seemed to have entirely missed the scientific nature of evidence that is the core business of at least some of these crime shows.

By contrast, six of the top eight crime show fans named particular crime shows while talking about the external uses of DNA, which may further indicate that one reason they watch these shows regularly and enjoy them, is for information they gain from watching. These specific differences in knowledge between the top eight and the bottom four students in Table 5.9 may constitute evidence that participating students have varied motivations for watching these shows.

> **Comparative Assertion T: Two thirds of participating students who nominated crime shows as favourites acknowledged these TV shows as sources of their genetics knowledge and expressed knowledge consistent with concepts depicted in these TV crime shows.**

Finally, favourite characters from the crime shows were revealing, although just 30% of the students listed them. Table 5.10 shows the votes for various characters received from the participants. Totals are:

NCIS:

- older male team leader Gibbs (6)
- young funky female forensic scientist Abby (5)
- male agent Tony (3)
- female agent Ziva (2).

Bones

- female forensic anthropologist nicknamed Bones (11)
- male FBI agent Booth (5).

*CSI'*s only vote for a favourite character was for the first team leader, Grissom, an older, serious, and rather eccentric man. *Cold Case* and *Law & Order*, each receiving only one vote for their lead female detectives, are not shown in Table 5.10.

Table 5.10

Favourite characters in crime shows nominated by students

Students	Total interview score (/30)	*CSI*	*NCIS*	*Bones*	*The Mentalist*
Annette Yr 7	25		Ziva		
Shanee Yr 7	24		Tony, Ziva	Bones, Booth	
Hanja Yr 6	24		Tony		
Katherine Yr 6	21			Booth	
Diana Yr 6	21		Tony		
Hailey Yr 7	20		Abby	Bones	
Saul Yr 7	20		Gibbs	Bones	
Skyla Yr 6	19		Gibbs		
Macey Yr 7	19		Abby, Gibbs	Bones	Patrick
Brian Yr 6	19			Bones	
Burnu Yr 7	17	Grissom	Gibbs		Patrick
Katrina Yr 5	14		Abby	Bones, Booth	
Clarenne Yr 5	12		Gibbs	Bones	
Tirranna Yr 5	11			Bones	
Parri Yr 5	11			Bones	
Geordana Yr 7	10		Abby		
Anne Yr 5	9			Bones, Booth	
Gia Yr 5	7		Abby, Gibbs		
Coorain Yr 5	6			Bones, Booth	

These results indicate a preference for leaders, particularly older strong males (Gibbs, Grissom, Patrick), and forensic scientists (Abby and Bones), rather than the action-oriented younger agents (Tony, Ziva, Booth), who might otherwise be expected to appeal to young people. Tony and Ziva only appealed to those who already had sound knowledge of genetics.

Comparative Assertion U: Participating students preferred older male leaders and forensic scientists to active police agents in the crime shows they viewed.

A preference for forensic scientists was not necessarily linked to knowing more about genes and DNA. The bottom eight students in Table 5.10 all voted for at least one forensic scientist but scored less than 15/30 on the interview. Several of these students have already been shown as not relating DNA to solving crime or having only rudimentary genetics knowledge.

However, Shanee, Hailey, Macey, Brian, and Saul also nominated forensic scientists as favourite characters. Shanee's knowledge appeared previously as Student Statement 9, Macey's as Student Statement 12, and Saul's as Student Statement 4. Hailey said that DNA in the blood controls what you look like, makes people who they are, and can be used to find out who has been murdered. She learned about DNA on *The News*, on *NCIS,* and from posters in hospitals. Hailey thinks, "Abby (from *NCIS*) is awesome." Brian knew that DNA could be used to identify dead people like on *Bones* and to find escapees, and thought DNA could be compared with photos. These ideas are consistent with their enjoyment of forensic scientist characters in these TV shows.

Collectively, the data pertaining to favourite shows and characters indicate that students who particularly enjoy crime shows fall into two groups. One group has little genetics information, not even knowledge that DNA is used to solve crime, and seems to find alternative appeal in the forensic scientists other than their specific work with DNA. The other group knows more about genetics, particularly about using DNA to solve crime, possibly from attraction to the forensic scientists in these shows.

So far, this chapter has examined interconnections at general and specific levels between multiple data sets, namely the media exposure data set and the genetics concepts in the media data set, with the participating students' genetics knowledge data set and the students' perceived sources of genetics information data set. The interconnections between these data sets were considered quantitatively and qualitatively, always with the possibility of negative cases and rival explanations in mind. The cross-comparisons of these multiple data sets also took into account the three theories of media influence described in Chapter 2. The correspondence of these findings with the three theories of media influence is discussed in detail in Chapter 6. However, one other possible interconnection between the data sets remained to be explored. This was the possibility of links between students' perceived sources and their knowledge.

Connections Between Perceived Sources and Students' Knowledge

The data were examined for quantitative interconnections between students' perceived sources of genetics information and their genetics knowledge. Figure 5.2 shows the comparison of number of reported sources and amount of genetics knowledge as measured by average interview scores for the 62 interviewed participants.
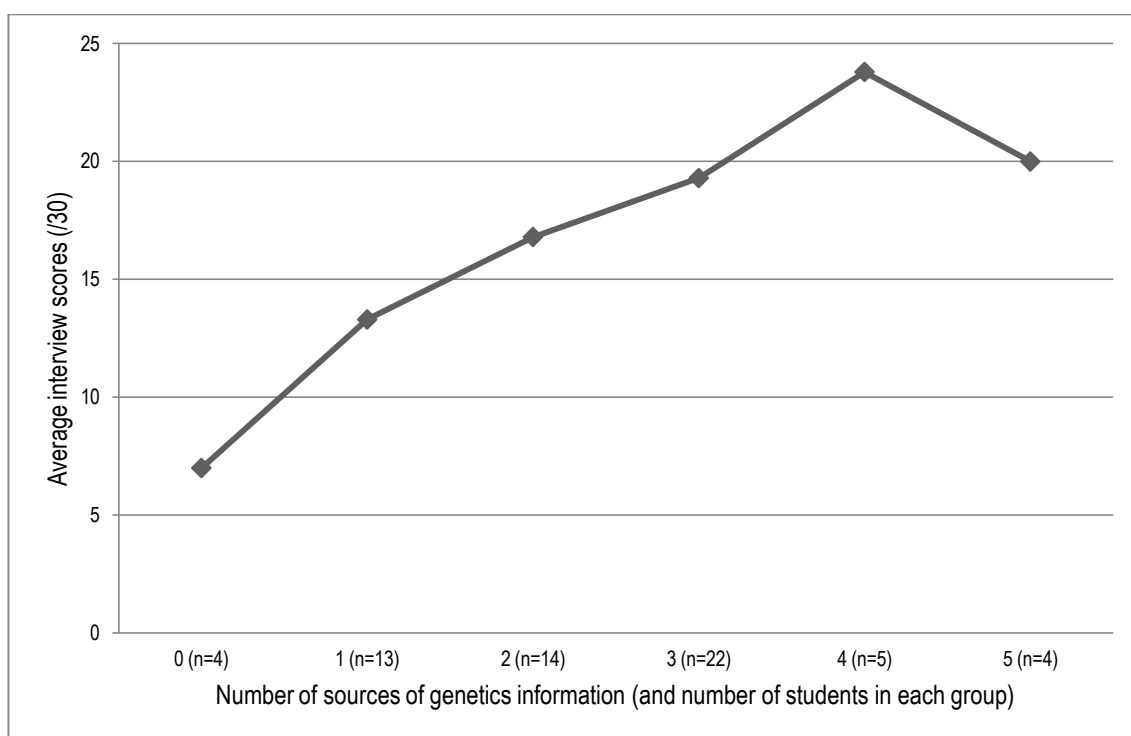
Figure 5.2. Relationship between number of sources of genetics information and average amount of genetics knowledge for all 62 interviewed students.

Figure 5.2 shows that genetics knowledge generally increases with number of sources of genetics information. The trend may actually peak at four sources, or the slight decline in knowledge with five stated sources could represent confusion in putting fragmentary information from so many sources together. The decline could also be an artefact of the small sample number in that group. This figure connects the findings described in Chapter 4 that students in the lowest SES group had the least knowledge (Genetics Assertion 3), as they also reported the fewest sources of genetics information (Sources Assertion c).

The data were examined qualitatively by selecting typical students whose individual data best matched the averages for interview scores and numbers of genetics misconceptions. The extracted statements of these typical students about genes and DNA are shown in Table 5.11.

Table 5.11

Statements about genes and DNA made by students typical to each group based on number of perceived sources of genetics information

Sources	Student	Student statements about genes and DNA
Zero	Coreen	I've not heard of genes or chromosomes, I think I've heard of DNA. A DNA test will show who you're related to.
One	Joel	If someone broke into a car, you can put a special powder over it, it shows up the fingerprints, then you get the DNA. I know because my Auntie's car was fingerprinted. And I've seen it before on *CSI,* I watch it with Mum but I'm not really watching it. DNA is only in the hands and feet.
Two	Cathleen	Babies take samples of DNA from Dad and Mum, but I don't look like my parents, I look like my aunties. Every living thing has DNA, inside your body. DNA is to make us all different, even twins don't have the same fingerprints. DNA is curly things with coloured dots round it (hand gesture in spiral). DNA tells us who we are related to. I learned about DNA from TV, the *News*.
Three	Skyla	A bit of both parents' DNA goes into the kitten sometimes, but it could just be from one parent. I got Dad's genes for eyes, but Mum's nose - genes could come from either parent or both. DNA is used to identify you, it's in hair, fingerprints and blood. Genes are what your parents give you, DNA identifies you, it's part of you. For crime, you can analyse hair or fingerprint to find a person. I've seen that on *NCIS*, though there's not much in that show about eyes. In forensics, you can use DNA to find who has stolen something.
Four	Elvie	Genes come from inside, they are microscopic and squiggly. They make you look like you are, short or tall. DNA can compare different people and find out how they're different. In cloning, we use DNA for making another exactly the same. Yes, DNA can be used to solve crime and for identifying a dead person. I learned most about DNA on *Home and Away* and the *News*.
Five	Eliza	I know more about genes, I know that they can be passed way through generations. Like if your great great grandparent has cancer, you might get it even if it missed in between. Genes and DNA are both in my brain and heart. I seen on TV that DNA looks like 2 pieces of wire bent, with little balls in between. DNA could be for your health, like healthy levels of blood sugar. I learned about DNA from Doctors, specialists, medical shows and crime shows. Also from magazines, lifestyle ones. A bit from school – about this research and about how bodies are made up. And when Mum talked about growing and changing bodies. Everyone's got similar and different genes in their fingers so we can go by fingerprints in crime. It can be used at the hospital, to find out what type of blood you've got. We use DNA to find out how they died and to find people from their family.

Table 5.11 indicates the knowledge increase with more reported sources seen quantitatively in Figure 5.2, is matched by increasing specificity of knowledge, about biology as well as external uses of DNA. Students in Table 5.11 selected as typical for groups formed by number of sources, were atypical of the total interviewed sample in that two knew the shape of DNA and one knew the size of DNA. Overall, twice as many students knew DNA was microscopic as knew its shape (Genetics Assertion 10).

> **Comparative Assertion V: Increased number of reported sources of genetics information was linked with increased amount and specificity of knowledge about genetics.**

Finally, Table 5.12 explores whether students who reported doing their own research into genes and DNA had gained useful genetics knowledge from their efforts. Although a subsample of 17 was marginal for a *t* test, two-tailed homoscedastic *t* tests with alpha < .05 were performed, with significant results. Cohen's *d* was calculated to see the size of this effect.

Table 5.12

Comparison of knowledge and number of sources between students who did their own research into genes and DNA (n = 17) and those who did not (n = 45)

Student group		*M*	*SD*	*p* value	Cohen's *d*
Own research (*n* = 17)	Genetics knowledge (/30)	20.88	3.87	.0003	1.15
	Number of sources (/5)	3.18	1.13	.001	.95
No research (*n* = 45)	Genetics knowledge (/30)	15.69	5.06		
	Number of sources (/5)	2.07	1.19		

Table 5.12 shows that students who conducted their own research into genes and DNA had significantly more knowledge than those who did not, evidenced by the *p* value of .0003 and a large effect size (Cohen's *d* in excess of 1). Given the relationship seen in Figure 5.2, some of the knowledge gained through students' own research could be due to their consulting significantly more sources, as evidenced by the *p* value of .001 and a large effect size (Cohen's *d* approaching 1). No significant difference in the average number of misconceptions held by members of these two groups (own research versus no research) was found.

These findings indicate that participating students aged 10-12 were able to gain meaningful knowledge from a variety of sources if sufficiently interested in the topic of genetics to conduct their own research.

Comparative Assertion W: Participating students who conducted their own research into genes and DNA expressed significantly more knowledge about genetics than those who did not.

Chapter Summary

This chapter explored interconnections between the data sets gathered for this research: students' exposure to the mass media, concepts about genetics in the mass media, specific mass media accessed by participating students, genetics knowledge expressed by participating students, and their perceived sources of information about genetics. Specifically, genetics themes in three different forms of the mass media (television, newspapers, and magazines) were consistent with each other and with the themes in genetics knowledge expressed by participating students. Crime and family relationships shows were watched by the majority of participating students, with varying levels of apparent acquisition of specific knowledge from those TV shows.

An in-depth analysis of concepts depicted in three crime shows focusing on DNA (*NCIS, Bones,* and *CSI*) revealed many specific similarities when compared with genetics concepts expressed in students' interview statements. Students who researched genes and DNA themselves had significantly more knowledge about these topics than students who did no active research. Overall, participating students tended to fall into two groups; a larger group whose results indicate the likelihood that much of their genetics knowledge has been derived from their exposure to the mass media, and a smaller and often younger group, generally possessing less genetics knowledge, for which the mass media as a major source is less certain.

Chapter 6 brings together the assertions of the findings stated in Chapters 4 and 5 and synthesises them into a manageable number of meta-assertions to form the basis of the discussion. This process facilitates an on-balance judgement of the findings, and further discussion of their relationship to the theories of media influence and other literature.

Chapter 6 – Synthesis and Discussion

This chapter synthesises, discusses, and situates the key findings, focusing on the assertions made throughout Chapters 4 and 5 as encapsulations of the main results. However, statistical data previously recorded in tables are included alongside the assertions where relevant in order to further inform the wording of the meta-assertions synthesised in this chapter.

Synthesis

Participants

Participants in this study were 141 students from Years 5-7 (ages 10-12 years) in various locations from large provincial cities to small remote towns in three states of Australia. All 141 students completed the media questionnaire, enabling statistical analysis of the quantitative findings concerning media exposure. From this large sample, I selected 62 students for individual face-to-face interviews to ascertain their genetics knowledge, misconceptions, and perceptions of their sources of genetics information. Once shown to be representative of the larger sample, this subsample of 62 interviewees became the main sample from whose detailed information most of the major findings explored in this chapter are drawn. In the next section, the key findings are addressed for each research question in turn, and drawn together into meta-assertions for subsequent discussion.

Research Question 1 - Media Exposure

1a) What level of exposure to the mass media do primary students report?

In Chapter 2, Tables 2.1 and 2.2 showed the mass media exposure for children in USA (Rideout et al., 2010; Van Evra, 2004). As noted in Chapter 4, media exposure for the participating Australian students was approximately one third less than for their US counterparts, but followed overall similar patterns. TV was the dominant medium, and media use increased with age. Boys used significantly more media in both countries, particularly E-games. Similarly, media exposure tended to increase as SES declined, although Sample 3, from outback NSW, was anomalous in several respects. Figure 6.1 combines assertions about the students' exposure to mass media to build an overall picture.

Assertions and other recorded data
Media Assertion I: Participants accessed television 2.5 times more than any other form of mass media.
Media Assertion II: Of the print media, participants accessed mostly magazines and newspapers.
Media Assertion VIII: Participants interacted with a wide variety of each type of mass media; favourites were not universal.
Comparative Assertion C: Crime shows have been viewed by most (79%) of the participating students, with *NCIS* and *Bones* being the most viewed shows.
Time spent with the mass media varies considerably, but averages 5 hr 50 min per day for boys and 4 hr 51 min per day for girls (from Table 4.2).

Figure 6.1. Overview of students' ($n = 62$) exposure to the mass media.

Collectively, the assertions in Figure 6.1 indicate that the mass media plays an important role in the lives of these Australian primary students, and that many are exposed to adult concepts about crime through their media choices. The assertions in Figure 6.1 are summarised in meta-assertion 1.

> **Meta-assertion 1: Participating students chose to access a wide range of mass media, including television, magazines, and newspapers, and the majority chose to view crime shows, especially *NCIS* and *Bones*.**

1b) What specific concepts about genetics are found in the media to which these primary students are regularly exposed?

Analysis of the genetics content of mass media named by the participating students yielded the assertions shown in Figure 6.2, creating an overview of the students' exposure to genetics concepts in the mass media.

Assertions and other recorded data
Media Assertion IX: Mentions of DNA, genes, and genetics were found to occur in many of the participants' favourite television shows (not just in crime shows).
Media Assertion XIII: Genetics content was prominent in articles found in participants' local newspapers.
Media Assertion XXII: Participants were most likely to view genetics concepts on television, and in magazines and newspapers.
Media Assertion XV: Eleven themes emerged from analysis of 102 newspaper articles referring to genetics concepts, of which disease and crime were the most prevalent.
Comparative Assertion A: Similar themes about genetics emerged from all three types of genetics-containing media used by participating students, that is, newspapers, magazines, and television.

Media Assertion XXI: In 102 newspaper articles about genetics, DNA was mentioned 206 times, gene was mentioned 140 times. This tendency to mention DNA more often was also noted in other forms of mass media.

Media Assertion XIX: In sampled newspaper articles, different suites of words were found for each theme; *gene* was most associated with disease or health, whereas *DNA* was most associated with crime and paternity.

Media Assertion XII: Images commonly associated with genetics content in the participants' local newspapers were light microscopes, DNA helix, and gloved hands holding vials and micropipettes.

Comparative Assertion F: Considerable technical equipment is associated with DNA in crime shows.

Comparative Assertion G: The light microscope often features in television shows and newspaper articles in which DNA and genes are mentioned.

Comparative Assertion H: Real equipment is used on TV shows that depict the analysis of DNA.

Media Assertion XIV: 60% of participants' local newspaper articles about genetics had no or poor scientific explanation of the genetics concepts.

Media Assertion X: In advertisements, DNA and genes were referred to in symbolic rather than scientific ways.

Media Assertion XI: Some magazines named as favourites by participants had genetics content, some of which was of dubious scientific accuracy.

Media Assertion XX: Only five percent of sampled newspaper articles attempted to explain the structural relationship between genes and DNA.

Media Assertion XVI: The presence of DNA in the nucleus of cells was very rarely mentioned in the sampled newspaper articles, appearing only in two articles about disease.

Media Assertion XVII: No newspaper articles specifically explained the biological function of DNA/genes, which is to produce proteins for growth and regulation.

Media Assertion XVIII: Chromosomes were rarely mentioned in the sampled newspaper articles, appearing in nine articles about disease and in an article about sex/gender.

Comparative Assertion E: DNA samples shown in crime shows include saliva, blood, skin, and fingerprints; students named these as locations of DNA.

Comparative Assertion K: Crime shows do not distinguish clearly between fingerprints for identification, fingerprints as a DNA source and the process of DNA fingerprinting or profiling.

Comparative Assertion M: Crime shows do not explain that only some parts of a person's genome is assessed, or the technical details of the process, but do indicate the type of information that can be derived from DNA profiling.

Comparative Assertion O: TV show plotlines reinforce links between DNA, blood, crimes, criminals, victims, and sometimes also disease and family relationships.

Figure 6.2. Overview of students' (*n* = 62) exposure to genetics concepts in the mass media.

Six meta-assertions were formed from the assertions in Figure 6.2 addressing different aspects of the data: Location of genetics content in the media, genetics-related themes in the media, equipment associated with genetics in the media, degree of explanation of genetics concepts in the media, genetics concepts rarely portrayed by the media, and genetics concepts commonly portrayed in the media.

Meta-assertion 2: Genetics content was principally located in a variety of television shows, local newspapers, and magazines.

Meta-assertion 3: Within eleven genetics-related themes in the media, DNA was mentioned most often, and associated with solving crime, identity, and paternity; genes were associated with disease, health, and families.

Meta-assertion 4: The light microscope was prominent amongst images of real equipment used in different media to signify working with DNA and genes.

Meta-assertion 5: Explanation of genetics concepts in the mass media is generally poor, or, in many cases, absent.

Meta-assertion 6: Genetics concepts rarely portrayed in the media include the structural relationship between genes and DNA, location of DNA in the nucleus of cells, the biological functions of genes and DNA, and chromosomes.

Meta-assertion 7: Genetics concepts commonly portrayed in the media include obtaining DNA from blood, fingerprints, saliva, and semen; and connections between DNA, solving crime, and various facets of identification.

Research Question 2 - Students' Expressed Knowledge of Genetics

2a) What is the level of primary students' conceptual understanding in genetics?

Key information sought in the interviews concerned knowledge that DNA/genes are responsible for inheritance, the biological functions of genes and DNA, and the structural relationship between genes and DNA. In a separate part of the interview, I asked students for their knowledge concerning uses of DNA outside the body. Figure 6.3 summarises

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the participating students' expressed knowledge of genetics by combining assertions and reported results.

Assertions and other recorded data

Only one student had no understanding of inheritance (Table 4.12).

Genetics Assertion 4: 61% of participant students knew that DNA and/or genes are responsible for inheritance of traits by offspring from parents.

18 students linked DNA to inheritance whereas 28 students linked genes to inheritance (Table 4.13).

Overall, 55 students (89%) knew or had heard of DNA whereas 37 (60%) knew or had heard of genes (Table 4.13).

Genetics Assertion 5: DNA was better known than genes by this sample of students.

Genetics Assertion 7: Knowledge that humans contain DNA and/or genes was almost universal (97% of students) in this sample.

Genetics Assertion 6: Participants rarely knew the term chromosome and did not associate it with inheritance.

Genetics Assertion 8: Only 11% of participants knew that DNA/genes are located in cells; none knew the precise location of DNA in the nucleus of cells.

Genetics Assertion 9: Only eight percent of participants knew both the small size and *twisty ladder* (helical) shape of DNA.

Genetics Assertion 10: Participants were twice as likely to know DNA was very small or microscopic as to know the shape of DNA.

Genetics Assertion 11: None of the participant students knew that DNA/genes work through directing the production of polypeptides or proteins.

Genetics Assertion 12: Only six percent of participants could describe the structural relationship between genes and DNA.

Genetics Assertion 13: Many more participants (94%) offered ideas about nonbiological (external) uses of DNA than could offer ideas about its biological nature and functions (only 6-8% of participants).

Genetics Assertion 14: 77% of participants said that DNA could be used to solve crime; this was the first use suggested by half of this group.

Genetics Assertion15: 64% of participants suggested that DNA could be used to identify family relationships; this was the first use suggested by more than one third of this group.

Genetics Assertion 16: 30% of participants suggested that DNA could be used to diagnose disease; first suggested by only one sixth of this group.

Genetics Assertion 17: 48% of participants suggested alternative uses of DNA such as cloning, identification, and research; half of this group gave their own ideas about uses of DNA first.

Figure 6.3. Overview of students' (*n* = 62) expressed knowledge of genetics.

The assertions in Figure 6.3 were synthesised to form four meta-assertions addressing different aspects of the data: Participating students' knowledge of different genetic entities, limitations of students' genetics knowledge, specific knowledge of the nature of DNA, and genetics knowledge common to many students.

> **Meta-assertion 8: DNA was known to nearly all participating students, who associated it with identity, whereas genes, known by more than half the students, were associated with inheritance and families.**

> **Meta-assertion 9: Limitations of participating students' genetics knowledge included not knowing the structural relationship between genes and DNA, the location of DNA in the nucleus of cells, biological functions of genes and DNA, and chromosomes.**

> **Meta-assertion 10: Twice as many participating students knew that DNA is microscopic than knew its shape.**

> **Meta-assertion 11: Common knowledge for most participating students was nonbiological uses of DNA, including solving crime, and resolving family relationships (both involving identification).**

2b) What misconceptions do primary students have about genetics?

As participating students answered open-ended questions about their knowledge of DNA and genes during their interview, their misconceptions about these topics became apparent. As Genetics Assertion 18 states, generally, those students with more genetics knowledge also expressed more misconceptions. This fits with learning theories as discussed in Chapter 2, which deal with ways in which students attempt to fit new information into their existing schemas as in cognitivism (Gagne, 1985), or frameworks as in constructivism (Vosniadou, 1994). In the absence of instruction and thoughtful attempts to guide the connections between incoming and existing ideas, as more information is gathered, there are more opportunities for haphazard connections to form, giving rise to beliefs that lack scientific accuracy, designated in this research as misconceptions. Figure 6.4 summarises the misconceptions expressed by the participating students in this doctoral research.

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Assertions and other recorded data
Genetics Assertion 18: Generally, participants who demonstrated more genetics knowledge also expressed more misconceptions.
Genetics Assertion 19: 21% of participants expressed a misconception that linked genes with family resemblance and DNA with unique identity.
Genetics Assertion 20: 13% of participants expressed a misconception that DNA's only function is to solve crime.
Genetics Assertion 21: 27% of participants expressed a misconception that genes and DNA are different things.
Genetics Assertion 22: 51% of participants expressed a misconception that DNA is only found in blood or forensic samples.
Genetics Assertion 23: 18% of participants expressed a misconception that DNA is only found in a few internal organs.
Genetics Assertion 24: 32% of participants expressed various misconceptions concerning gene expression (K6, K7, K8, K9, K11, K18, and K20).
Genetics Assertion 25: 44% of participants expressed novel misconceptions concerning gene/DNA function (M1-M8).
Genetics Assertion 26: 11% of participants expressed novel misconceptions concerning transfer of genes/DNA (M9-M14).
Genetics Assertion 27: Eight percent of participants expressed novel misconceptions concerning the nature of genes/DNA (M15-M18).

Figure 6.4. Overview of students' ($n = 62$) expressed misconceptions about genetics.

The assertions in Figure 6.4 were summarised in four meta-assertions.

Meta-assertion 12: Participating students' misconceptions mainly arose from a limited view of DNA's location (in blood, other forensic samples, a few organs), and function (to solve crime, to resolve family relationships).

Meta-assertion 13: Separation of DNA from genes in terms of structure and function was expressed by approximately one quarter of participating students.

Meta-assertion 14: Genetic determinism commonly arose in the expressed ideas of participating students, particularly concerning genes for complex traits such as abilities, thoughts, behaviour, and personality.

Meta-assertion 15: Novel misconceptions appeared to be mostly limiting beliefs or extrapolations from known information into inappropriate realms.

Given these findings, I concur with Hirsch (2006) and Willingham (2006) that background knowledge is an important adjunct to learning. However, I contend that teachers should acknowledge possible sources of background knowledge, and provide guidance to assist students to piece the knowledge together appropriately and move towards scientifically accurate frameworks.

Research Question 3 - Students' Perceptions of Information Sources

From where do primary students believe they have learned about genetics?

Participating students were asked for their perceptions regarding their sources of the genetics information that they expressed during the interview. Only four students (6%) had so little genetics knowledge that they also had no sources to mention. Only eight (13%) of students who mentioned any sources did not mention TV. Figure 6.5 summarises the findings for this research question.

Assertions and other recorded data
Sources Assertion b: 81% of participants named television as a source of their knowledge about genes and DNA.
Sources Assertion d: 37% of participants named television as their first source of genetics information and a further 29% named it as their second source.
Sources Assertion f: Television crime shows were the participating students' main perceived sources of genetics information.
Sources Assertion a: Only 20% of participants reported learning about genetics from their parents, and for half of them, it was through overhearing adult conversation rather than direct discussion.
Sources Assertion e: Some learning from books was incidental, but 27% of participants reported having done their own research into genes and DNA using books and/or the Internet.
Sources Assertion c: Students in the lowest SES sample (Sample 4), had the fewest perceived sources of genetics information.

Figure 6.5. Overview of students' ($n = 62$) perceived sources of genetics information.

The assertions in Figure 6.5 were combined to form two meta-assertions.

Meta-assertion 16: Television, particularly crime shows, was the predominant perceived source of genetics information for participating students.

Meta-assertion 17: More participating students have researched genes and DNA independently than have directly discussed this topic with their parents.

The finding that low SES groups rely mostly on TV and few other sources for information is consistent with US studies (Van Evra, 2004). The finding that participating students rarely talked to their families about genetics was consistent with Weiner et al.'s (2003) research. Their conclusion was that in the absence of family talk, the lay public use the media, particularly television and newspapers, to comprehend human genetics. However, the finding that more than a quarter of the participating students of this age had done their own research into genes and DNA was unexpected.

Research Question 4 – Interconnections

What connections can be drawn between genetics concepts in the media, participating students' reported media use, and their genetics conceptions?

Finding connections involved cross-comparisons of the data sets. Figure 6.6 summarises the findings pertinent to this research question.

Assertions and other recorded data
Comparative Assertion B: The same genetics themes that emerged from the mass media were found in participants' expressed genetics knowledge.
Comparative Assertion J: Data from 74% of participating students support a connection between the viewing of crime-related TV shows and knowledge of the use of DNA to solve crime.
Comparative Assertion P: 40% of participating students linked DNA to criminals and evidence in ways similar to that portrayed in crime shows.
Comparative Assertion L: 38% of participating students linked fingerprints to DNA but most did not distinguish clearly between using fingerprints for direct identification, fingerprints as a DNA source, and the process of DNA fingerprinting/profiling.
Comparative Assertion T: Two thirds of participating students who nominated crime shows as favourites acknowledged these TV shows as sources of their genetics knowledge, and expressed knowledge consistent with concepts depicted in these TV crime shows.
Comparative Assertion U: Participating students preferred older male leaders and forensic scientists to active police agents in the crime shows they viewed.
Comparative Assertion N: 14.5% of participating students were aware that DNA could be matched by machines, and were viewers of crime shows and other TV shows known to contain genetics content.
Comparative Assertion Q: Viewing medical shows and other health-related sources of information may result in students closely associating DNA with blood.
Comparative Assertion R: The family relationship show *Find My Family* links inheritance (and hence genes and DNA) with blood, as do half of the regular viewers of this TV show.
Comparative Assertion S: Viewers of family relationship shows linked DNA with paternity and the capacity to identify people to resolve family relationships.

Figure 6.6. Overview of connections observable in students' (*n* = 62) responses

These connections involved all the collected data sets, including the detailed analysis of the *10 TV shows of interest*, comprising seven crime shows and three shows about family relationships. The comparative assertions in Figure 6.6 were drawn together in three meta-assertions indicating connections found in the data.

Meta-assertion 18: Responses of three quarters of participating students indicate connections between their viewing of TV crime shows and knowing that DNA can be used to solve crime.

Meta-assertion 19: Specific knowledge expressed by participating students with regard to DNA, solving crime, fingerprints, scanning machines, and DNA databases was consistent with the ways these concepts are depicted in crime shows they have viewed.

Meta-assertion 20: The propensity of some participating students to link DNA with blood was connected with their viewing of TV shows about medicine and family relationships.

Collectively, the 20 meta-assertions synthesised in this chapter represent the major findings of this doctoral research. The remainder of this chapter discusses these findings and situates them within the known literature. The meta-assertions concerning the mass media are compared with those about students' knowledge. This achieves the overarching aim of the research, which was to explore possible links between the ways genetics concepts, particularly the concepts of genes and DNA, are portrayed in the mass media and the development of primary students' conceptions and misconceptions about the nature and function of genes and DNA. Reference is also made in the discussion to specific findings located within Chapters 4 and 5, and to Appendix D, which contains statements about DNA from all interviewed students.

Discussion

This research, being exploratory in nature, cannot seek nor claim causal relationships. Livingstone (1996) and Van Evra (2004) both noted that it is extremely difficult to control all variables in order to elucidate a cause and effect relationship in media influence research, and that appropriate approaches, such as those used in this doctoral study, yield useful inferences, correlations and trends.

Orthia et al. (2012) called into question the very notion of media influence, due to the diversity of responses from the adult participants in their study. Adults have been shown to absorb less information per hour of TV than children who are learning about the world (Fowles, 1992). The research by Barnett et al. (2006) and Orthia et al. (2012) considered responses to just a single viewing of source material, rather than ongoing interactions with many similar sources of information as this research does. Mann (2006) stated that regular viewing is likely to leave more of an impression. Thus the students in this doctoral study, aged 10-12 years, are likely to be easily influenced by repetitive exposure to similar sources, such as crime shows.

The studies of Barnett et al. (2006) and Orthia et al. (2012) also created an artificial situation, in that the viewing occurred at school as a class group or with the whole focus group present. Anderson and Collins (1988) found that knowing that recall of content would be tested increased attention and mental effort, which would increase the apparent influence of the viewing. In contrast, this doctoral research explored the influence of the totality of mass media of their own choosing with which Australian primary students reported interacting at home. Evidence that such influence occurred represents a "phenomenon worthy of concern" (Anderson & Collins, 1988, p. 9) in that such knowledge acquisition could have ramifications for future learning.

In this study, the results are weighed to see if, on balance, the findings indicate the possibility of influence from the mass media upon the understandings about genetics of the participating primary students. To that end, the meta-assertions concerning the media and those concerning the genetics understandings of the students and their sources of genetics information are juxtaposed in Table 6.1 to facilitate comparison of the findings between the two domains of this research.

Table 6.1

Comparison of findings about the media with findings about the students

Meta-assertions about the media	Meta-assertions about the students
Meta-assertion 2: Genetics content was principally located in a variety of television shows, local newspapers, and magazines.	Meta-assertion 1: Participating students chose to access a wide range of mass media, including television, magazines, and newspapers, and the majority chose to view crime shows, especially *NCIS* and *Bones*.
Meta-assertion 16: Television, particularly crime shows, was the predominant perceived source of genetics information for participating students.	Meta-assertion 18: Responses of three quarters of participating students indicate connections between their viewing of TV crime shows and knowing that DNA can be used to solve crime. Meta-assertion 19: Specific knowledge expressed by participating students with regard to DNA, solving crime, fingerprints, scanning machines, and DNA databases was consistent with the ways these concepts are depicted in crime shows they have viewed.
Meta-assertion 3: Within eleven genetics-related themes in the media, DNA was mentioned most often, and associated with solving crime, identity, and paternity; genes were associated with disease, health, and families.	Meta-assertion 8: DNA was known to nearly all participating students, who associated it with identity, whereas genes, known by more than half the students, were associated with inheritance and families.
Meta-assertion 6: Genetics concepts rarely portrayed in the media include the structural relationship between genes and DNA, location of DNA in the nucleus of cells, the biological functions of genes and DNA, and chromosomes.	Meta-assertion 9: Limitations of participating students' genetics knowledge included not knowing the structural relationship between genes and DNA, the location of DNA in the nucleus of cells, biological functions of genes and DNA, and chromosomes.
Meta-assertion 7: Genetics concepts commonly portrayed in the media include obtaining DNA from blood, fingerprints, saliva, and semen; and connections between DNA, solving crime, and various facets of identification.	Meta-assertion 11: Common knowledge for most participating students was nonbiological uses of DNA, including solving crime, and resolving family relationships (both involving identification). Meta-assertion 20: The propensity of some participating students to link DNA with blood was connected with their viewing of TV shows about medicine and family relationships.

Meta-assertion 4: The light microscope was prominent amongst images of real equipment used in different media to signify working with DNA and genes.	Meta-assertion 10: Twice as many participating students knew that DNA is microscopic than knew its shape.
Meta-assertion 5: Explanation of genetics concepts in the mass media is generally poor, or, in many cases, absent.	Meta-assertion 13: Separation of DNA from genes in terms of structure and function was expressed by approximately one quarter of participating students.
	Meta-assertion 14: Genetic determinism commonly arose in the expressed ideas of participating students, particularly concerning genes for complex traits such as abilities, thoughts, behaviour, and personality.
	Meta-assertion 15: Novel misconceptions appeared to be mostly limiting beliefs or extrapolations from known information into inappropriate realms.

Table 6.1 indicates that the media forms in which most genetics content is located (television, newspapers, magazines) are also the media forms readily accessed by the participating students. However, students' use of television far outweighs their use of the print media, making television the single most important source of genetics information as 81% of participating students acknowledged. In particular, most of the students watched crime shows, and cited these shows as important specific sources of information about genetics. Supporting this, the specific knowledge about genes and DNA expressed by the students was consistent with the ways in which these genetics concepts are depicted in the crime shows.

Table 6.1 indicates that the media mentions *DNA* more often than the word *gene* and similarly, that more students mentioned DNA than mentioned gene. Student responses paralleled what is portrayed in the media in terms of associations of words and concepts – DNA with identity, genes with families. Similarly, there was a direct correlation between four specific genetics concepts rarely portrayed in the media, such as DNA's location in the nucleus of cells, and genetics concepts known by 10% or fewer of the participating students. Conversely, most students knew specific genetics concepts commonly portrayed in the media, such as DNA's use in solving crime. Specifically, Genetics Assertion 13 indicated that only 6-8% of participating students offered biological uses for DNA, but 94% offered nonbiological uses, including 77% saying that DNA is used to solve crime. The media commonly shows DNA collected

from blood, fingerprints, saliva, and semen and half of the students expressed the misconception that DNA is only found in these tissues, particularly blood.

On television and in print media, the light microscope is a prominent image of equipment associated with DNA, despite the fact that the double helix cannot be viewed under this instrument. Nonetheless, this association may explain why twice as many students knew that DNA was microscopic than knew its shape. The double helix image was only rarely seen in the media, an unexpected result compared with Nelkin and Lindee's (2004) report. In Australian media, DNA, and particularly the helix, appeared in a symbolic way in advertising, rather than in entertainment programming.

Table 6.1 indicates that the explanation of genetics concepts is absent or poor in the media, which may explain why students hold a number of misconceptions. Specifically, some of the media's shorthand ways of referring to genetics, such as genes for particular diseases or traits, were reflected in the deterministic responses of some students.

In addition, meta-assertion 17 (not included in Table 6.1) indicates that twice as many participants in this research did their own research into genes and DNA than discussed the topic directly with their parents. Chapter 5 detailed that students who conducted their own research expressed significantly more genetics knowledge than those who did not (Comparative Assertion W). Students conducting their own research also reported significantly more sources of genetics information, which Comparative Assertion V shows is linked to increased quantity and specificity of knowledge about genetics. Although 20% of students cited parents as sources of genetics information, in about half the cases, the students overheard conversations between adults, rather than directly discussing genetics with their parents. Van Evra (2004) points out that if parents do not coview and discuss television with their children, then television becomes the major source of knowledge for children. Collectively, these findings indicate that participating students, particularly those who deliberately sought to gain genetics knowledge from the media, are capable, to an extent, of assimilating meaningful knowledge about genes and DNA.

In this section, the weighing of evidence leads to the conclusion that it is highly likely that participating students have obtained some, if not all, of their knowledge about genetics from their interactions with the mass media. The specific conceptual information about genetics that students have gained, particularly from entertainment media, may be of academic and personal relevance in their future lives. The findings from this study concerning genetics also points to the possibility of other scientific

concepts being acquired from the mass media, for example about nuclear power, and climate change, which would also be worthy of concern. The next section considers the findings of this doctoral study through the lenses of the three theories of media influence in order to elucidate how such influence might have occurred.

Theories of Media Influence

Three theories of media influence described in detail in Chapter 2 comprise the cultivation theory as espoused by Gerbner et al. (1980, 1982, 1986, and 1994), the social learning/social cognitive theory (Bandura, 1977, 1994), and the uses and gratifications theory (Rubin, 1984, 1985, 1994; Comstock & Scharrer, 1999). The findings from this research are considered with respect to each theory in turn.

Cultivation theory.

According to the cultivation theory (Gerbner et al. 1980, 1982, 1986, and 1994), exposure to greater *quantities* of media should result in greater media influence. In the context of this research, quantity could refer to two aspects of the data: total media saturation or exposure to only genetics-containing media. More influence should mean more genetics knowledge.

Assertions made in Chapter 4 based on total media saturation indicate that a simple cultivation effect is not occurring. Media Assertion III stated that participating boys used significantly more media overall than girls, yet Genetics Assertion 1 reported no significant difference in the genetics knowledge of participant boys and girls. Similarly, Media Assertion VII indicated that media exposure increased with declining SES, but Genetics Assertion 3 showed that genetics knowledge decreased.

It could be argued that overall media saturation scores masked any cultivation effect as boys also played significantly more E-games than did the girls, and E-games had minimal genetics content. However, the Genetics-Containing Media (GCM) scores reported in Table 4.9 also showed that the boys' results are significantly different from the girls. Consequently, if a cultivation effect was occurring, boys, exposed to significantly more genetics-containing media, should have more genetics knowledge than did the girls, yet Genetics Assertion 1 showed this was not the case. This does not mean that the media is not a source of their genetics knowledge, but that there is no simple arithmetic relationship between the quantity of media and the degree of influence, as would be predicted by the cultivation theory.

Social learning/social cognitive theory.

The social learning/social cognitive theory (Bandura, 1977, 1994), predicts that *quality*, or nature of the content, determines its degree of influence. Bandura's main interest was in behaviour rather than knowledge acquisition. However, the social cognitive theory predicts that those students exposed to media with explicit genetics content should have knowledge that mimics that content, as they model their knowledge on what they have seen and heard. At a general level, social cognitive theory predicts that genetics themes in the mass media should parallel themes in students' responses. As juxtaposed in Table 6.1, meta-assertions 3 and 8, and the specific assertions from which these are drawn, indicate that considerable similarity in themes and word associations was found.

As shown in Table 6.1, meta-assertions 7 with 11 and 20, 4 with 10, and 16 with 18 and 19, indicate modelling at a more detailed level. Participating students demonstrated specific genetics knowledge that clearly modelled that which they had encountered in the media. Students expressed detailed knowledge of specific processes seen on crime shows such as common sources of DNA found at crime scenes, and the process of comparing DNA with sequences on computer databases. Student Statements in Chapter 5 showed that students used language echoing that used in the media, such as evidence, victim, suspect, criminal, DNA fingerprints, crime scene, and forensics. Orlando (2009) reported that forensic experts never use the word *match* when giving DNA evidence in court, but that crime shows do. Participating students such as Shanee (Student Statement 9), Willis (Student Statement 10), Cherilyn (Student Statement 20), and Hanja (Appendix D) all used the word *match* to describe DNA comparison. Given that the students' reported sources of genetics information included a heavy reliance on TV and limited information from other sources such as parents, it is hard to explain this explicit knowledge expressed by these young students as being sourced from outside of TV crime shows.

Therefore, the results indicate that the social learning/social cognitive theory has explanatory power for the findings of this study.

Uses and gratifications theory.

The uses and gratifications theory (Rubin, 1984, 1985, 1994; Comstock & Scharrer, 1999) contends that the key determinant of influence is the *users' motivations and*

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needs. This is reflected by media preferences, the use made of the mass media, and patterns of use. Comstock and Scharrer (1999) suggested three key motivations, from most to least important, as being escape, self-evaluation, and information-seeking. According to this theory, people who watch the same television show with different motivations would have different outcomes in terms of influence.

Specifically, as Van Evra (2004) states, the theory predicts that students who watch shows for escapism would expend less mental effort on following the details; in the case of this study, they may be more interested in the action and might learn less about genes and DNA from their viewing of crime shows. Conversely, it is assumed that students may use entertainment to gain information they need (Van Evra, 2004); in this case, students whose motivation is information-seeking should learn more about genes and DNA from their exposure to the same crime shows. Finding this pattern in the data for students' favourite shows and characters from these shows may indicate that students may be watching with different motivations. However, as the interview questions did not explicitly ask students about their motivations for watching specific TV shows, such conclusions are speculative.

There is some evidence in the data for this theory of media influence at work. For example, in Chapter 5, Year 5 twins Arunta (Student Statement 3) and Alkira reported watching the same TV shows, with different outcomes in terms of genetics knowledge. Arunta displayed more knowledge than did his sister; a possible explanation is that his motivation for viewing crime shows is information-seeking, whereas Alkira may view the crime shows for other reasons such as escapism. In addition, students such as Annette (Student Statement 11) mentioned discussing things they saw on TV with parents, or were motivated to do their own research, possible evidence of an information-seeking motivation at work.

The uses and gratifications theory also helps to explain the *viewers but nonlinkers* group of 12 students in Table 5.7, who regularly view crime shows but who did not link DNA to solving crime. Nine of this group of 12 students were in Year 5 (i.e. 10 years of age), and Genetics Assertion 2 reported a significant increase in knowledge from Year 5 to Year 6, but no further increase from Year 6 to Year 7. Rubin (1985) found that use of TV for excitement peaks at 10 years of age and decreases as age increases to 17 years, thus excitement/escapism is explicable as the Year 5 students' main motivation for viewing crime shows. Gibbons et al.'s (1986) finding that younger students remember action better than utterances, affords further explanation for the finding of less

knowledge. Crime show audiences hear the word DNA more often than they actually see the substance of DNA. Cullingford (1984) showed that the amount remembered is inversely related to the amount watched, as those who watch more pay less attention and do not try to remember. Jemilia, a member of the group of viewers but nonlinkers, watched more crime shows than did any other student, but knew little about DNA.

Overall, despite not specifically asking participating students about their motivations for watching particular TV shows, the uses and gratifications explains some of the findings from this research.

Chapter Summary

The review of literature in Chapter 2 indicated a widespread belief that the mass media influences people, and persuasion campaigns appeared to result in acquisition of knowledge about the issue rather than in behavioural change. However, little was known about the prospects of people, students in this case, acquiring specific conceptual knowledge from the mass media, particularly from entertainment media that they choose to watch at home.

In this chapter, 20 meta-assertions were synthesised from the 78 assertions made from the findings presented in Chapters 4 and 5. These findings form the basis of the discussion and conclusions from this research. Juxtaposing the meta-assertions facilitated weighing the evidence and achieving the overarching aim of exploring links between the participating students' media exposure and their understandings of genetics. On balance, the evidence indicated strong interconnections between these two domains. Aspects of genetics commonly presented in the mass media were commonly known by the students. Very few students knew aspects of genetics rarely presented in the mass media. In particular, some specific aspects of the participating students' expressed knowledge of genes and DNA, including considerable vocabulary, would be difficult to explain as having arisen from any other source besides the mass media.

However, the findings also indicated that the mass media do not influence all students in the same way at the same time. Again, this statement does not imply a definitive causal relationship; here the nuance of meaning of the word influence is "power to sway" (Merriam-Webster's Dictionary, 2012). Of the three theories of media influence, cultivation effect offers limited explanatory power for these results. Quantity, in and of itself, is not the main determining factor for learning. Social learning is likely to be occurring as student answers do model, for the most part, what they have

witnessed in the media with which they have engaged. In terms of their specific knowledge of crime and exposure to relevant television shows, three quarters of the students express ideas consistent with social learning/cognitive theory. The uses and gratifications theory also offers explanatory power for some of the results in terms of why some students who watch crime shows do not acquire information regarding the scientific nature of DNA evidence. They may be watching these shows for escapism, whereas others, who appear to gain a lot of knowledge about genetics from crime shows, may be watching from an information-seeking motivation. Overall, social learning/social cognitive theory and the uses and gratifications theory offer more explanatory power for the findings of this research than the cultivation theory.

In the final chapter, Chapter 7, consideration is given to the degree to which all the aims of this research were achieved, to the implications arising from the findings, both for students and for educators, to issues of trustworthiness and limitations, and lastly, to future directions.

Chapter 7 – Conclusions

Achievement of the Aims of this Research

The overarching aim of this research was to explore possible links between the ways genetics concepts, particularly the concepts of genes and DNA, are portrayed in the mass media and the development of primary students' conceptions about the nature and function of genes and DNA. This was to be achieved by investigating four specific research questions. The results of this investigation, as presented, discussed, and synthesised in Chapters 4, 5, and 6, indicate the likelihood that many conceptions and misconceptions that the participating students had about genes and DNA have arisen from their interactions with the mass media. Possible means by which this may have occurred were elucidated by examining the findings through the lens of three theories of media influence. However, there were three other lesser aims of this research.

The first aim was to check whether misconceptions found previously were common to a wider sample of students. Prior research only involved students in metropolitan Western Australia in 2003 (Venville & Donovan, 2005c). That limitation became the rationale for sampling in three different states and in nonmetropolitan areas for this doctoral research. The findings of this doctoral research, detailed in Figure 6.3 and encapsulated by meta-assertions 8, 9, 10, and 11, indicate that the students' expressed knowledge was very similar to that expressed by students of similar ages (described as the younger group) in prior research (Venville & Donovan, 2005c). The percentage of students spontaneously mentioning DNA/genes as being responsible for inheritance was similar, being 56% of the younger group in the prior study and 61% of the students in this study. In the prior study, there were no questions about uses of DNA outside the body, but some students volunteered information about solving crime and using DNA to identify people, and named the mass media as a source of that information. Participating students in both studies were generally unaware of the biological functions of DNA, its location in the nucleus of cells, knew little of chromosomes, and did not link chromosomes with inheritance. Replication, more than five years apart and in such diverse populations, increases the capacity to generalise the results of both studies, at least to the general Australian population of students of this age group.

A second aim was to find out where the students themselves thought their information came from, as this had only been hinted at in previous studies. The findings

indicate that participating students were astute in terms of awareness of where genetics concepts are found in the media. Several correctly noted that there was more information about DNA in TV shows such as *NCIS, Bones*, and *CSI*, than in *The Mentalist, Law & Order,* and *Cold Case* (for example, Shanee, Student Statement 9; Annette, Student Statement 11; and Cherry, Student Statement 14, in Chapter 5). This finding also points to the general honesty of the students, and indicates that they took the research seriously and tried to provide accurate and truthful answers.

A third aim, to be achieved by the selection of sample locations, was to compare populations from different areas, particularly those with free to air access to *CSI* compared with those who lacked such access. This aspect of the research was less successful, as students simply watched whatever crime shows were on air where they lived. *Bones* was ubiquitous to all sampled areas, and watched by many students, and, although not all students had free access to *NCIS*, it was the most watched of the crime shows of interest (as shown in Figure 5.1). Of the three DNA-focused shows, the participants watched *CSI* the least, despite it previously being "blamed" as the culprit in terms of students' misconceptions. Therefore, as students who viewed *CSI* did not know more about DNA than students who did not view *CSI*, there was no educational "CSI effect." However, the findings indicate a more general "crime show effect" in that most (though not all) students who watched any or all of *CSI, NCIS,* or *Bones* expressed specific knowledge consistent with what is depicted in these shows. In her unpublished doctoral dissertation based on an intensive study of three African-American high school students, Johnson-Whitt (2012) also found that her students expressed specific ideas about forensic science and scientists consistent with the ways in which these topics are depicted on *CSI*, and contrary to their perceptions of school science. Johnson-Whitt did not examine the effect of *NCIS* or *Bones*.

In Chapter 1, I discussed the original CSI effect and its influence on the decisions of jurors. Although debate still rages as to whether viewing *CSI* and related shows makes jurors more likely to acquit or convict, most justice system researchers agree that jurors are expecting more scientific evidence to be presented at trial than would usually be the case. This has implications regarding access to required scientific equipment, personnel, costs, and time taken to solve crimes. A key criticism aimed at *CSI* is that it misleads the public in terms of how quickly DNA tests can be achieved (for example, MCAO, 2005; Orlando, 2009; We're the real CSI[27]). However, during the 12-year run of *CSI*, technology has improved considerably; for example, extraction of DNA from

fingerprints is now possible (Choi, 2003), and costs and time may decrease due to inventions like the portable DNA analyser (Quilty-Harper, 2007). Technology may have been driven to improve in part by its presentation on such television shows, although not all jurisdictions would have access to such advanced and costly equipment.

It is also pertinent to consider that only the youngest of today's jurors have watched *CSI* and similar TV shows from preadolescence. Most would have been exposed as adolescents and adults, with *CSI,* the first TV crime show to focus on displaying details of forensic procedures, commencing in 2000. In the USA, various large-scale studies (for example, Baskin & Sommers, 2010; Willing, 2004), have consistently found that about 70% of the adult population watch crime shows on television. Baskin and Sommers' (2010) study of over 1,200 randomly selected adults further found that 16% of them watched more than five hours of crime shows per week. This doctoral research found that 71% of the 62 interviewed students had watched at least one of *CSI, NCIS,* or *Bones*; more than half of those students are regular viewers of these three DNA-related TV shows, and 13% of them watched five or more hours of crime shows per week. These findings are remarkably similar to those for US adults. This doctoral research also demonstrated that 89% of the interviewed participants knew about DNA, and 77% associated it with solving crime. These students are only aged 10-12 years; they have another 6-8 years of potential viewing of similar shows ahead of them before being eligible for jury duty.

The popularity of such TV depictions of crime and ways to solve it shows no sign of diminishing, making these years of potential viewing realistically achievable. The Monte Carlo TV Festival[76] awarded *CSI* the "International Television Audience Award (Best Television Drama Series)" award four times (up to and including 2011). The series also spawned two spin-offs, *CSI: Miami* and *CSI: New York*, both high rating, although *CSI: Miami* may be coming to an end. After a slow start in 2003, the popularity of *NCIS* steadily climbed to a rating of number one in the USA and it is Australia's top-rated US show (Chozick, 2009). As reported in *The West Australian* (February 8, 2012), *NCIS* has now reached the 200th episode with no sign of slowing. It has also spawned a successful spin-off, *NCIS: Los Angeles. Bones* began in 2005, and continues to rate well, although its spin-off series, *The Finder*, was cancelled after one season (*The Hollywood Reporter,* May 9, 2012). These combined findings raise a future probability of increased incidence of the CSI effect in terms of future generations of jurors demanding increased scientific evidence, and of the "crime show effect" for people's conceptions of genetics.

<blockquote>*Implications of the Findings*</blockquote>

Implications for both students and educators arise from the findings of this doctoral research. Implications for students involve their academically relevant knowledge in the near future and their science literacy as future citizens. This research informs educators about students' misconceptions and readiness to learn more about genetics, raising issues regarding addressing or preventing misconceptions, and about when genetics should be included in the curriculum. These implications are considered in the following sections.

Implications for Students

Academically relevant knowledge for later school experiences.

Wood (1993) suggested that genetics taught in schools and genetics discussed in the media were too different for effective learning to occur; however, this suggestion was not based on empirical evidence of genetics in the media. The findings of this doctoral research indicate that by the time students are aged 10 or 11 years, most have acquired specific knowledge about genes and DNA, with the mass media being the most likely source of much of that knowledge. This expressed knowledge does not resemble school genetics, in that few students were able to talk about the biological functions of genes and DNA, nor did they mention Punnett squares, pedigrees, or meiosis; all ideas remaining to be taught in Year 10. The genetics understandings apparently derived from the media included external uses of DNA such as solving crime and cloning, and linking DNA to identity, and genes to families.

Wood's (1993) research found that her students saw differences where science sees similarities, and that her students focused on phenotype where science focuses on genotype. Consistent with her observations, the findings of this doctoral research indicated that students focused on the role of DNA in making a person unique and identifiably different from anyone else, and linked DNA directly to phenotype in stating that by looking at your DNA someone could tell what you looked like. Wood (1993) explained that students with these ideas would experience difficulties in future learning of genetics, particularly if gene regulation and polygenes were not taught. I concur with this statement.

Not all knowledge expressed by the participating students in this doctoral research was scientifically accurate; many students also held misconceptions about genetics. These misconceptions were mostly due to incomplete or one-sided knowledge, rather than completely inaccurate knowledge. For example, DNA *is* found in blood and tissues

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collected as forensic samples; the misconception is the belief that DNA is *only* in these tissues. Developing the balance of the knowledge could address such misconceptions; in this example, by explaining that DNA is in the nucleus of nearly all cells in the body, but that the tissues students see collected as sources of DNA on crime shows are merely convenient ways to obtain samples that might be left behind at crime scenes.

Misconceptions concerning the fundamental nature of genes and DNA, such as the belief that they are structurally and functionally different, are likely to become a major difficulty when students encounter formal genetics in Year 10. It will be very difficult to reconcile their construction of understanding with information about meiosis and inheritance, particularly if the way in which genetics is taught does not start with explaining these structural relationships. In this respect, the Australian curriculum (ACARA v3.0, 2011) is helpful, as the elaborations to the base statement about heredity begin with DNA, and encourages the establishment of relationships between DNA, genes, and chromosomes before moving to meiosis and inheritance. However, as Sneider and Ohadi (1998) stated, misconceptions can be easier to change in younger students. Misconceptions that have been held for 3-5 years (from Year 5, 6, or 7 to Year 10), will not be easily challenged. Teachers would also need to be aware that students hold such misconceptions in order to challenge them.

Scientific literacy in future lives.

As a science educator, I am just as concerned about my students' future lives as citizens as I am about their chances of successfully negotiating academic genetics in Year 10. As detailed in Chapter 1, I firmly believe that science literacy and science media literacy skills are essential for life in this century of genomics and proteomics. The National Assessment Program – Science Literacy [NAP-SL] (2010) indicated a need for concern, reporting 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, such as the participating students in this research, was significantly lower than that of children in metropolitan regions (NAP-SL 2010). I await the results of the next round of testing in 2012. So an important question is what does this doctoral research say about future science literacy?

The findings of this research indicate that participating students held a wide range of genetics understandings, from simplistic beliefs that DNA is dangerous and kills people, to sophisticated thoughts about what happens to DNA when we die. On balance,

most students expressed more knowledge than expected. In presentations of these findings to date (such as Donovan, 2010; Donovan & Venville, 2011, 2012c), audiences have been universally amazed at the amount, specificity, and level of knowledge expressed by students aged only 10-12 years, although also alarmed at the misconceptions expressed in terms of impact on future understandings. In Chapter 2, I made a case, based on the work of researchers such as Hirsch (2006) and Willingham (2006), for the importance of background knowledge in terms of driving understanding, problem-solving and reasoning. In Chapter 1, Roberts (2007) was noted as saying that science knowledge was essential for scientific literacy. Thus, finding that students are acquiring background knowledge at an early age bodes well for future science literacy in genetics, but only if that knowledge can be assimilated and constructed into useful and accurate theoretical frameworks.

The findings indicate that much of the participating students' current knowledge about genes and DNA is fragmentary, much like diSessa's (1993) p-prims. For example, students may have heard of DNA, genes, and possibly chromosomes, but have not linked this knowledge with appropriate structural or functional relationships. Other students say that DNA is needed to identify a suspect at a crime scene, but that genes are needed to find out if someone is adopted, and give no indication that they think that these two ideas are related in any way. However, some students with more genetics knowledge, as indicated by their interview scores, linked the ideas together to say that genes are what make a person resemble their family whereas DNA is what makes that same person unique. This could be evidence that these students are attempting to construct these fragmentary p-prims about DNA and genes into simple theories. Another example is the finding that some students extrapolated the idea that DNA is in the blood, to a theory that DNA may also be grouped, donated, and changes colour in response to oxygen. Unfortunately, such simple theories are not necessarily scientifically accurate. Clearly, guidance is required to assist students to construct scientifically accurate frameworks from their acquired background knowledge, thus achieving a measure of scientific literacy.

The Australian curriculum (ACARA v3.0, 2011) does not, in its present form, go far enough to create sufficient genetics literacy to understand issues such as genetic modification of crops, why not all people who smoke get lung cancer, or to comprehend risk in genetic counselling. By not requiring alleles, gene function, proteins, polygenes, or the influence of the environment to be taught, students will not be equipped to deal

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with the details of many genetics-related issues. This research indicates that the mass media rarely mention the biological functions of genes, and that the level of explanation is absent or poor; consequently, students are unlikely to gain sufficient scientific literacy from the media *or* their compulsory education.

Science media literacy skills.

To make any sense of genetics issues aired in the media, given the poor levels of explanation found in many articles, students need high-level science media literacy skills. Students need to evaluate sources, be expert at locating reliable information, and be able to extract accurate science knowledge from that presented. Their capacity to achieve these skills, and to be appropriately sceptical and critical of that which is presented in the media, is little known and yet crucial.

Research has considered general media skills; for example, Collins (1982) found that children may not fully understand television until 8th Grade, and Gadow, Sprafkin, and Watkins (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. Yet relatively little research has been done to bridge general media literacy skills with those specifically required for science media; indeed, so little that Alexander, McClune, and Jarman (2010, [Title]) called this bridge "the missing link." In their media literacy conference paper, they reported on a novel intervention of bringing science and english subjects, teachers, and Year 10 students together for a day. The findings were positive; when the teachers of the two subjects found that they analysed science newspaper articles in different ways, the novel interdisciplinary approach enabled the teachers to recognise this difference and to discuss a common ground for the future. Both teachers and students enjoyed the experience of bringing the disparate subjects together, and felt it would be worthwhile to continue a cross-curricular, embedded approach to media literacy. I believe this would be an equally valuable exercise for Australian teachers and students.

Murcia (2009) demonstrated that Australian students are not acquiring adequate science media literacy skills with current tuition. She reported that more than 50% of Australian first-year university students failed to demonstrate an ability to engage critically with media science as presented in the news. In particular, they were unable to engage with reported methods, and were insensitive to the notion of a community underpinning scientific research. Murcia (2009) concluded there was a definite need to teach students the necessary skills for such critical engagement.

Collectively, this body of research indicates that students need to be taught media literacy skills in school; they are unlikely to acquire them unaided. The findings of this doctoral research show that students in Years 5-7 are choosing to interact with media intended for adults, such as television crime shows. It would seem, therefore, that these year levels would be optimal for helping students develop their media literacy skills, in science as well as in other learning areas, especially as primary teachers are used to teaching across disciplines. Ideally, this cross-curricular approach to media literacy should then continue throughout the compulsory education in high school. If students are not taught how to decode genetics in the three main media in which they encounter it (television, newspapers, magazines), and develop their ability to pinpoint the inaccuracies in what is said about genes and DNA, then they cannot be said to be developing complete scientific literacy in genetics.

Is this achievable? In a report focusing on new digital technologies, as well as traditional media, Jenkins (2007) suggested that media literacy should not be seen as an add-on, but as a paradigm shift, that reshapes how every subject, including science, is taught. Specifically,

> Media change is affecting every aspect of our contemporary experience, and as a consequence, every school discipline needs to take responsibility for helping students to master the skills and knowledge they need to function in a hypermediated environment. (p. 57)

The report by Jenkins (2007) points to students who have been very successful at young ages due to the skills gained from their interactions with digital media outside of school, and then offers many suggestions of what could be done in schools to promote similar success. Jenkins lists 11 core skills, and offers specific ideas that science teachers could use to facilitate the development of those relevant to the processes and practise of science: simulation, distributed cognition, collective intelligence, judgement, transmedia navigation, networking, and negotiation.

It is clear that students need explicit guidance to develop science literacy and science media literacy. Consequently, implications for students, in terms of their lives as future school students and citizens, become implications for educators, both teachers, and curriculum designers.

Implications for Educators

As just discussed, there is a pressing need for educators to teach science literacy and science media literacy explicitly. This doctoral research also uncovered 18 misconceptions previously unknown in the genetics education literature, as well as the current incidence of several of those already known. What is the likelihood of these misconceptions being mitigated by future teaching and learning in genetics?

Under the current system of teaching all genetics in Year 10, the outlook is not promising for the future genetics understandings of these students. Misconceptions observed in the participating students will not be addressed for 3-5 years, and then, only if classroom teachers know such misconceptions might exist, and take the time to reveal and challenge them as they teach. In the crowded curriculum, this is unlikely. As described in Chapter 2, genetics education researchers already know the outcomes of this "one-shot system." Most existing research considers older students who have been through this approach, and findings show that it fails to produce appropriate student understanding of genetics. Misconceptions remain, and few students are recorded as making it to stage 4 of Venville and Treagust's (1998) framework, where they understand genes as productive instructions for proteins. In current curricula, attempts to merge students' existing understandings of DNA, such as its use in solving crime, or resolving family relationships, with "school DNA" are unlikely to occur. Students are interested in cloning, but classroom conversations focus on this topic as an ethical issue, rather than on the technicalities of different types of cloning and the role of DNA. Miller (2006) concluded by inference that the public media was the sole source of students' knowledge about cloning, noted many misconceptions and students' lack of accurate knowledge about the many types of cloning, and called for an emphasis on media literacy skills development in schools.

Echoing the words of Dhingra (2003), and also noting the lack of prior research into the influence of media on student understanding of scientific concepts, Barnett et al. (2006) set out to show whether, to effectively teach science, educators need to understand how popular culture (their term for the mass media) influences students' perceptions and understanding of science. Finding that a single viewing of a science fiction film had a negative impact on the understandings of middle school students, Barnett et al. (2006) responded by having their preservice teachers critique the science in a film or television show that they had watched. The researchers hoped that this experience would encourage the preservice teachers, when they move into teaching, to

have their students do likewise. This is a useful strategy, and indeed, research has shown that it is also important to address the science misconceptions of teachers. Specifically, Mills Shaw et al. (2008) and Cardak and Dikmenli (2008) called into question the genetics misconceptions held by teachers in the USA and Turkey, and pointed to a need to challenge and address these before improvement in the incidence of student misconceptions would eventuate. Teachers need ready access to research, the time to read it, and willingness to challenge their own thinking in order to improve their own understandings and overcome their misconceptions. The most likely timing of confluence of these factors is when they are preservice teachers.

Can genetics be taught earlier in schools? The participating students' level of interest, leading 27% of the interviewees to do their own research into these topics, does call into question the appropriateness of the Australian Curriculum: Science which leaves formal education about these topics until Year 10. Outcomes education's catchcry has been "start from where they're at" (Curriculum Council, 1998) and it would appear from these results, that these young students believe themselves to be ready for at least the fundamental principles concerning the nature of genes and DNA. Comparative Assertion W showed that those who had done their own research tended to score highly on the interview in terms of genetics understandings, some achieving very sophisticated knowledge, such as Prasai, a Year 6 boy (Table 4.18), and Willis, a Year 6 boy (Student statement 10 in Chapter 5).

Is interest a possible indicator of readiness? Is there value in capitalising on students' interest when it arises? Based on three decades of empirical research, Suzanne Hidi would answer "yes" emphatically. In Hidi and Renninger (2006), a four-phase model of interest development is described. Briefly, the four phases are:

1. Triggered situational interest – sparked by something external
2. Maintained situational interest – focused attention on the external trigger
3. Emerging individual interest – seeking out opportunities to engage again
4. Well-developed individual interest – enduring engagement.

Hidi and Renninger (2006) note that phases one and two are nearly always externally supported, and phases three and four benefit from external support. Indeed, they consider early support as critical, as it is then that educators are most able to help students feel positive about their emerging capacity to work with the content. Without such support, any phase of interest development can become dormant, regress or disappear. Hidi and Renninger (2006) consider the educational implications of their

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research as demonstrating the need for teachers to foster triggered interests, to ask curiosity questions to sustain interest, to encourage students to ask their own curiosity questions, and to select or create resources that promote problem-solving so students can develop their interest and their understanding. In terms of this doctoral research, the four phases of their model of interest development could be exemplified as:

1. Triggered interest sparked by seeing DNA used to solve a crime
2. Maintained interested by noticing every time DNA is used to solve crimes
3. Emerging interest by deliberately watching crime shows and looking for the use of DNA to solve crime
4. Well-developed interest by researching DNA and how it can be used.

The findings of this research indicate that 27% of the interviewed students have moved to Phase 4 without support from educators, although perhaps they found support from families and friends. Student statements as recorded in Chapters 4, 5, and Appendix D, indicate that the majority are in Phases 1 and 2 of interest in terms of genes and DNA, given their knowledge of the terms, and their ability to link terms with specific aspects of genetics in the media. Capitalising on this interest in primary school would be a valuable way of promoting student engagement, and potentially consolidating and sustaining students' interest in genetics until they reach Year 10 and encounter the main teaching of genetics. Otherwise, with 3-5 years to wait, and with no external support of their interest in genetics, it is likely that their interest in the topic will regress and disappear. Indeed, in prior research (Donovan & Venville, 2005c; Venville & Donovan, 2005d), I found the Year 9 students I interviewed treated genetics as decidedly "ho-hum" and displayed very little interest, despite my best efforts to enthuse them.

Age is not a barrier to interest – preschoolers may develop prodigious interest in dinosaurs and become young palaeontologists, capable of rattling off complex dinosaur names such as *Tyrannosaurus rex* with ease (Renninger & Wozniak, 1985). This highlights another key point; complexity of subject matter is also not a major barrier when interest is high. Hidi and Renninger (2006) noted that 11-13 year old students, classified as low ability based on achievement testing, but who had well-developed interests in reading or mathematics, out-performed higher ability students who lacked such interests. On this basis, students in Years 5-7 who express interest in genetics topics should be capable of tackling at least some of the complexity, and indeed, the

findings of this research indicate that some quite sophisticated understandings were expressed as well as thoughtful curiosity questions asked.

More recently, Hagay and Baram-Tsabari (2011) wrote of a shadow curriculum, pointing out that students, the recipients of education, are rarely, if ever, consulted about what they would like to learn. They asked 343 Israeli students to generate questions of interest, half of which were about genetics. Hagay and Baram-Tsabari then tested these questions out on another group of 375 students to see how generalised the interest was, and genetics scored highly. Most of these questions would not be addressed in the National Curriculum of Israel. The students in their study were in their later years of schooling, yet generated questions included "How can a DNA sample identify a person? Is there a difference in the number of genes an offspring receives from the mother and father?" Answers to these questions are the subject of misconceptions amongst some of the participating students in this doctoral research, and others knew the answers, despite their much younger age. Hagay and Baram-Tsabari (2011) also pointed out that interest is a form of intrinsic motivation (p. 613), that there were some gender differences in topics of interest, and that what teachers find interesting does not necessarily relate to what students find interesting. They suggested that using brainstorms and having students generate their own questions (which Hidi referred to as curiosity questions) would enable teachers to capitalise on student interest and motivation.

All of this research aligns with Tytler and Osborne's (2012) review which suggested that students are highly interested in science at 10 years of age, and form their career aspirations by age 13 or 14. It would seem critical to capitalise on the interest students aged 10-12 exhibit in genetics, particularly in the ways in which DNA can be used to solve human problems, and use this as motivation to learn more about the fundamentals of genetics. Broadening their background knowledge at this age would be likely to enhance future interest, and understanding.

How could genetics be taught earlier? What could or should be taught? As discussed in Chapter 2, learning progressions already exist for starting the study of genetics at Year 5. From the findings in this doctoral research, Duncan et al.'s (2009) proposed learning progression would seem to fit well with just one suggested change. In their learning progression, genes are introduced in Grades 5-6, but DNA is not mentioned until Grades 9-10. Given that participating students both in this research and in prior research (Venville & Donovan, 2005c; Venville, Gribble, & Donovan, 2005) were more familiar with DNA, and that one of the enduring misconceptions involves

thinking that DNA and genes are separate entities, it would seem sensible to introduce "genes made of DNA" right from the start. With this modification, Duncan et al. (2009) would have students in Grades 5-6 learning:

- Organisms have genes made of DNA in their cells

- Genes are instructions for how organisms grow, develop, and function

- Cells carry out many functions to live; bodies have levels of organisation

- Different cells have some common and some different structures and functions

- Cells divide to make new cells with each having all the genetic information, and in larger organisms, each parent contributes half the genetic information to offspring

- There are variations in traits within and between groups of organisms due to different genetic information

- The environment can affect traits so that even related organisms may end up looking or behaving differently.

Duncan et al. (2009) introduce chromosomes, meiosis, and alleles that produce proteins that carry out the functions of cells at Grades 7-8, and the details of DNA structure, replication, mutation, protein structure, and gene regulation at Grades 9-10. This would extend students' knowledge far beyond the requirements of the current Australian Curriculum: Science (ACARA v3.0, 2011), but would satisfy the essential understandings as suggested by the expert geneticists as detailed in Chapter 2. Effort would need to be made by teachers to present these concepts in "some intellectually honest form" (Bruner, 1960, p. 33).

To this end, models may be of assistance. Prior research with which I was involved (Donovan & Venville, 2005b; Venville & Donovan, 2007, 2008) detailed in Chapter 2, indicated that very young students (7 years of age) could use a simple model of wool to establish the basic relationship between DNA, allele, gene, and chromosome. Rather than routinely working with such young students, I would recommend that this model be used with students in Years/Grades 5-6 to establish the physical relationship between genetic entities as Duncan et al.'s (2009) learning progression is implemented. This model also proved useful in later years of schooling (Venville & Donovan, 2008), allowing students to refine their conceptions.

The use of models in science teaching and learning has been extensively researched, of which examples in the field of genetics include the work of Cartier and Stewart (2000), Roseman et al. (2006), and Gericke and Hagberg (2010). Some researchers have devised their own models, and others have looked at historical models in the field of genetics, but the crux of the research is that models are useful, although it is essential to clarify to the students what the model accurately represents and what it does not. It also becomes apparent that to progress students through the models to achieve higher levels of understanding of genetics, a "one-shot approach" is unlikely to be successful. Rather, students should engage with simple models early on, and encounter models of increasing complexity as they spiral through their learning of genetics, in full knowledge that each model, including my simple wool model, does not represent the whole story.

Does evidence exist that students could learn genetics effectively at ages 10-12? Besides my prior research detailed throughout this thesis, other researchers have found that students are capable of more sophisticated understandings than generally expected. Duncan, Freidenreich, Chinn, and Bausch (2011) worked with middle grade students with some success, deducing that promoting genes, proteins, and their effects on cells is an important goal for genetics education in the middle grades (p. 165). Dairianathan and Subramaniam (2011) reported on the success of an out-of-school intervention for 5th Graders in Singapore, which resulted in considerable learning of genetics. The 5th Grade students rated the intervention highly in terms of enjoyment and interest, with only one of the students finding the content too difficult. Dairianathan and Subramanium (2011) concluded that with relevant activities, appropriate cognitive load, and innovative lesson delivery, these topics could be successfully introduced to students of 11-12 years of age (p. 1104). Their research showed how much was achievable with one short session of well-delivered material. The findings of Dairianathan and Subramanium (2011) support my contention that students at primary school are capable of learning such material, and enjoy doing so. I would not recommend classroom teachers attempt to cover so much information in so little time, but engage in appropriate activities and classroom conversations throughout the year as students encounter genetics concepts. For example, when a student talks about what they saw on TV about DNA, supporting their interest by using my wool model or a substitute to add explanation may result in similar knowledge gains.

Are primary educators willing to improve their knowledge to teach these concepts to their students? I have only anecdotal evidence from this research. During lunchtime casual conversations with the classroom teachers in all sampled schools, I posed the question as to whether they would be prepared to teach some fundamental genetics, and whether they felt they would need professional development to do so. I was encouraged by their answers, which indicated that as cross-curricular teachers, they were used to researching many areas for their teaching. None said that adding the basics of genes and DNA to that list would be too difficult. Older teachers commented that such research was a lot easier these days with the Internet, especially in remote areas. However, support would obviously be beneficial; one teacher suggested that a list of reliable websites to improve teacher understanding, and any websites particularly useful for their students, would be much appreciated. This would not be difficult to provide, but the comment perhaps indicated that some teachers are not overly confident in their own science media literacy skills in terms of deciding the reliability of websites.

The argument presented above may sound overly simplistic, and I am aware of considerable literature concerning science teachers' content knowledge, the difficulty teachers have in acquiring and maintaining up-to-date content knowledge, and the impact the strength of their content knowledge has on their teaching and the learning of their students. For example, Horizon Research (2010), the Maths and Science Partnership aspect of the USA's National Science Foundation, produced a thorough review of 11 studies of teachers' science content knowledge. Realistically, not all primary teachers are likely to learn sufficient genetics to teach the basics effectively; but I was encouraged that teachers approached in this research were *willing* to learn and teach these topics.

The body of literature discussed in this section, and the findings of this doctoral research, have led me to conclude that the main implication for curriculum designers is to consider seriously the inclusion of some genetics in the primary school curriculum. Such a change would capitalise on student interest, engage students in real world science connecting with the science they encounter in the media, combine the expertise of students and teachers to discuss science seen in television shows, and provide opportunity for students to engage with critical genetics understandings several times during their educational development. If students entered Year 10 with sound understandings of the physical nature, location and relationship of DNA, genes, alleles, and chromosomes, then the Year 10 genetics curriculum could move beyond the outdated emphasis on Mendel, dominance, and Punnett Squares. There would be time,

opportunity, and sufficient foundation to develop key concepts such as the role of proteins, influence of the environment, gene regulation, and polygenic inheritance in humans. The research summarised in this section predicts that such an approach would greatly enhance the likelihood of students achieving higher level understandings than has been possible with a "one-shot approach." Ultimately, such a new approach may help to develop students' science literacy and science media literacy skills to yield citizens capable of making important genetics-related decisions in their future lives.

Summary of Implications

This doctoral research was triggered by "blame" ascribed to the mass media, particularly to *CSI*, for contributing to students' misconceptions in genetics. Is that blame fair? I do not believe it is. Firstly, the participating students watched *NCIS* and *Bones* more than *CSI*. Secondly, the most glaring scientific inaccuracies occurred in print media rather than on television. Television is an effective teacher, but it presents a one-sided view of genes, and particularly, of DNA. Television teaches how humans use DNA to solve crime, diagnose disease, and identify people. It appears to prepare people to be jurors in trials with DNA evidence; raising the expectation that forensic evidence is the norm, which in reality, is not the case. Television does not appear to produce 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, and they appear to do that successfully, even with students younger than their target audience. The main side effect of such 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 (Science, Engineering, Manufacturing, Technologies Alliance [SEMTA], 2004).

It is up to educators to grasp the opportunities this interest provides and engage students with the science behind what they see. I know teachers who used the film *Jurassic Park* as a vehicle to discuss cloning. Although that was undoubtedly good practice, students may only watch that movie a few times. I assert that it is much more important to engage students 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 students 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 students make informed decisions in their future lives.

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"All field work done by a single field-worker invites the question; why should we believe it?" (Bosk, 2008, p. 167). At the commencement of this doctoral study, this quote provided tremendous incentive to me to critique continually the believability of my findings. Indeed, the preceding implications are only relevant if they are based on trustworthy data. In this section, the strengths and limitations of this doctoral research are examined prior to considering future directions and closing remarks.

This research utilised an exploratory, nonexperimental design in mixed modes. This design aimed to ascertain whether there was any evidence of possible influence of the mass media on student conceptions of genes and DNA, and to produce findings that might, in a limited capacity, be generalisable to a population as well as being explanatory for individuals. It was recognised from the outset that influence could be either positive or negative, and that both analysis and synthesis of the wide-ranging data would be required. How trustworthy are the results of this process?

Firstly, the design as detailed in Chapter 3 was carried through the entire research process. As presented in Chapters 4, 5, and 6, both quantitative and qualitative research tools were used, both types of data were yielded, analysed, and synthesised. Quantitative methods were applied to the larger data set of media data, which enabled major trends to be verified as statistically significant and for effect sizes to be calculated. Quantitative analysis also indicated that subsample data were not strong enough due to low sample sizes for reliable analysis of the data by regions, but did verify that the subset of interviewees sufficiently resembled the whole sample population to be a viable basis for detailed qualitative analysis. The research tools were developed based on considerable literature research as indicated in Chapter 3, and the success of this research in producing appropriate tools was demonstrated by the ease with which students responded to the media questionnaire and interview questions. The processes by which the qualitative data were reduced, displayed in graphs and tables, and verified were in accordance with the recommendations of Miles and Huberman (1994) and Creswell (2007). Appropriate analytical methods such as conceptual content analysis (Krippendorf, 2004), content analysis (List, 2005), and typology (Patton, 2002) were employed. Qualitative and quantitative findings were brought together during synthesis, reducing 78 separate Assertions, some quantitative, some qualitative, to 20 meta-assertions. These formed the basis for the discussion of the findings.

This study was designed independently to explore the Australian situation with respect to a specific interest; that is, the potential mass media sources of young students' understandings about genes and DNA. It was not intended to replicate or emulate the US studies by Rideout et al. (2010). That the overall results indicate similar patterns of media exposure is a general indicator that the way of life for children of this age is similar in both countries; and also that the method used in this study is at least as suitable as the variety of methods used in US studies to ascertain media exposure. In addition, the findings indicated that students obtain genetics content from the same media sources as identified by Bubela and Caulfield (2004). This study did not consider the issue of framing as Bubela and Caulfield (2004) did, but I did find evidence of deterministic presentation of genetics in the media as did Brechman et al. (2009). Creswell (2009) suggests that the literature is a benchmark with which to compare the results of a study with other findings. Had this study found very different results, questions would have been raised as to whether this was a real difference between USA and Australia or whether it was an artefact of the design and methods. That the findings of this doctoral research are compatible with what is known in the literature adds to the believability of the findings.

Also strengthening the design and execution of the research, and thus the trustworthiness of its findings, was the employment of four forms of triangulation, (Denzin, 1978; Janesick, 1994; Patton, 2002), the attention to descriptive validity (Padgett, 1998), an audit trail (Padgett, 1998), and to avoiding intuitive data processing (IDP) biases (Sadler, 2002), all described in detail in Chapter 3. Rigour was also enhanced through peer review (Allende, 2012), by using specialist statisticians, presenting findings at conferences (Donovan, 2010; Donovan & Venville, 2011, 2012c), and the publication of two papers in special issues of quality peer-reviewed journals (Donovan & Venville, 2012a; Donovan & Venville, 2012b). Reviewers' comments were used to improve this thesis as well as the papers in question.

It would undoubtedly have been easier to study the effects of a single viewing of a show, as did Barnett et al. (2006) and Orthia et al. (2012). However, my interest was more in the real world, and the possible influence of repeated viewings of many similar messages in different media. I also wanted to create a general picture of Australian students' interactions with the media, their genetics understandings, and their perceptions of important sources of science information. I recognised that all of this information was missing from the literature, and opted for a broad brush approach in

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order to create a sketch of the answer that can be further refined with future research. Thus, to look for a "phenomenon worthy of concern" (Anderson & Collins, 1988, p. 9), it was essential to cast a wide net. Although this added complexity and multiplied factors to take into account, it is also one of the strengths of this research, as the findings represent the real world of the participants and are therefore more likely to be generalisable to other Australian primary children.

Limitations

All research operates with certain limitations, many of which are unavoidable. These limitations are acknowledged here in four categories:

Sampling.

Sample sizes of 141 surveyed participants and 62 interviewees is large in comparison with some studies (for example, Lemish and Rice observed 16 children in 1986, Barnett et al. interviewed 38 students in 2006), but I would have preferred to interview more students had it been possible to extend the time available in some schools. Due to the desire to sample students in multiple locations and constraints associated with permission from multiple education authorities, only independent schools were sampled. Necessary ethical requirements limiting research to volunteers meant a more targeted cross-section of available students could not be selected, which may have rectified slight boy/girl imbalances and created larger subsamples in some regions. Necessary reliance on SES data published for one year to select sample schools for the following year could not account for changes in communities in the meantime, which meant that the samples were no longer ideally spaced with regard to SES. This also meant that the intended pooling of two smaller subsamples was contraindicated, preventing quantitative analysis for nuances of regional diversity. Finally, time considerations meant that only a limited sample of television crime shows could be analysed in depth, and discourse analysis of both these television show transcripts and students' statements was limited to gross considerations such as the SPEAKING grid (Hymes, 1974), rather than extended to specific analysis of individual utterances.

Data collected.

No consideration could be given to the Amount of Invested Mental Effort (AIME) (Salomon, 1981, 1983, 1984) in terms of students' interactions with the media. Thus, when students reported their perceptions of how much time they *usually* spend with TV, it is not clear whether this represents the amount of time they actually pay attention to

TV or merely how much time they are in its presence when it is on. Concurrent activities (such as reading, eating) may also interfere with mental effort paid to the TV show. To investigate AIME and the influence of concurrent activities, hidden video cameras would need to be set up in any room where students had access to TV in their homes, to assess visual attentiveness. Specific questions would target the information on the TV at those moments in order to ascertain mental attentiveness. This was not possible for this research, and has been achieved in only a few instances reported in the literature (for example, Anderson, Field, Collins, Lorch, & Nathan, 1985). Some aspects of data collection were unclear; for example, watching TV could include watching DVDs rather than live TV. From their answers, particularly of students in areas where popular shows such as *NCIS* were not available free-to-air, it seems that students reasonably interpreted the question as referring to watching television shows, whether live or on DVDs, as opposed to using the television for other purposes such as playing E-games. Another unclear aspect was the category of *News* in terms of sources of genetics information. From the students' answers, this was interpreted as an amalgam of news programming from television, radio, newspapers, and the Internet, as distinct from entertainment programming. General books and medical TV shows (as shows of interest) should have been included on the questionnaire.

Honesty.

Data collected by survey and interview rely upon the honesty of the participants. Van Evra (2004) cautions that participants may show a response bias by answering most questions positively (or negatively), or may give answers perceived as socially desirable or "right" (p. 29). I found no hint of response bias, and the breadth and depth of the students' answers, including their willingness to admit to being involved with some forms of the mass media for more than five hours at a time, point to inherent honesty rather than an awareness of political correctness. As an experienced interviewer, I did not observe any signs of "hedging" during the interviews; students appeared to tackle the questions promptly, without undue hesitation. The students readily opened up, and many became comfortably chatty beyond the specific questions. Only one student completed the media questionnaire and then erased some of his answers; he was not selected for interview and his desire not to have the erased aspects of his information used was respected. The capacity of children to estimate time is also questioned (Anderson & Collins, 1988), especially for very young children (preschoolers and early primary school age). The participants in this research were older, aged 10-12 years, so

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all were expected to be able to tell the time. It was observed that nearly all students wore a wristwatch and readily answered the question concerning their rising and bed times. Most gave accurate estimates of the length of time they would spend at the movies, their least frequent media interaction. Also asking them to estimate the *usual time* encouraged them to select answers normative for them, rather than a response based on an unusual recent event.

Other potential participants.

Time constraints also prevented the more active involvement of teachers with this research, with findings limited to casual conversations to ascertain that genetics had not been formally taught, and whether teachers would be willing to extend their teaching into this area in future. The design and timing did not allow for consultation with parents, but this would have been useful to cross-check students' perceptions of their media interactions, and also to ascertain what knowledge parents possessed about genes and DNA.

Future Directions

Many lines of inquiry are opened from the findings of this research. Explicated under three categories of replication, extension, and application, these include:

Replication of this Research

It would be useful to replicate this research, firstly, within Australia to improve sampling numbers in lower socioeconomic status areas to probe for regional variation. As the two smallest-population samples in this research were so different from each other that data could not be pooled, this indicates the possibility of significant variation in such populations. Secondly, in other countries, to explore whether children in other places and cultures yield similar findings with respect to their overall media interactions, genetics conceptions, and connections between viewing of specific television shows and types of knowledge expressed about genes and DNA. It would also be worthwhile replicating the part of this research in which students were asked for their perceptions of their sources of genetics information to ask them about their sources of other science information, such as about climate change, nuclear power, and medicine. This would test whether the media is their major source for all topical science information or for only some topics.

Extension of this Research

Extension would facilitate probing some of the findings to be explored in more detail. For example, students could be specifically asked about their motivations for watching certain television shows, and why particular shows and characters were nominated as favourites, considered in passing in this research. This could shed light on students' motivations and capacity to gain information from the media. Experimental studies in which students are shown particular episodes or clips of television shows containing specific science information, with pre and post testing of their knowledge, could uncover details of how and why certain knowledge is acquired whereas other knowledge is not. Extension of this research protocol into other areas of science information, such as climate change, nuclear power, and medicine, all common in the media, could ascertain how and when students learn about these topics, and how this learning differs from school science treatment of these topics. Claims that genetics could be successfully taught to younger students could be tested by instituting a spiral curriculum (Bruner, 1960) such as Duncan et al.'s (2009) learning progression in some pilot schools and following the students' progress with a longitudinal study. Further research into the specific concepts embedded within examples of the mass media is also required. For example, the way in which DNA has been presented over the 12 years of *CSI* could be examined for consistency or evolution over time. The cumulative effect of so much viewing of certain types of media such as crime shows, and concerns regarding underage viewing of such shows, could also be addressed through further research.

Application of this Research

As noted in both the replication and extension sections, this research could be applied to consider other science content, and to consider the knowledge of other participants, adults in general, parents, and teachers in particular. A comment in one TV show that TV had educated even toddlers to know how to treat a crime scene, could prompt investigation to find out at what age students first appear to be influenced by such shows, and whether young students do know about crime scene protocols. It is probably fortuitous that prior research has shown that students recall more from TV than from print (Walma van der Molen & van der Voort, 1998), as this research found that genetics presented on TV was generally more accurate than that presented in print. Further research could be aimed at finding out why this is the case, and work towards improving the quality of presentation of genetics in all media. The findings of this doctoral research could be applied to education research in general, by increasing the

awareness of teachers and researchers to factor into their paradigms the possible impact of students acquiring science knowledge from the mass media. The findings could also be applied to research concerning the development of preservice teacher programmes aimed at reducing the science misconceptions held by teachers, particularly about genetics, and at encouraging and empowering them to facilitate the development of their own, and their future students, science literacy and science media literacy.

Concluding Remarks

This research is the first to explore the possible influence of entertainment mass media on children's academically relevant knowledge, particularly in genetics. It found that students aged 10-12 chose to have substantial interaction with the mass media (averaging 5 hr 15 min/day), much of which has genetics content. Themes emerging from analysis of the genetics content of the mass media used by the participating students were similar to those emerging from analysis of their conceptions of genes and DNA. Specifically, the most common themes related genes to disease and inheritance, and DNA to solving crime, resolving family relationships, and personal identity.

The mass media was 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 of the participating students 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 students having heard of it, genes less so (60%), and chromosomes poorly known (19%). This approximates the ratio of coverage in the mass media, with DNA mentioned more often than genes, and 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 students believed DNA to be restricted to blood and other tissue collected for forensics, and offered several external uses for DNA.

Evidence for the interest of the participating 10-12 year old students in knowing about genes and DNA is that 27% of them have done their own research into the topic. If taught in developmentally appropriate ways, such as using a concrete model, as in prior research (Venville & Donovan 2007, 2008), and supported by the findings of Dairianathan and Subramaniam (2011), children may grasp the fundamental concepts of the nature and relationship of DNA, gene, allele, and chromosome even at this early

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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 students. I acknowledge that this research has not, and could not, demonstrate cause and effect, but I believe it has positively 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. 9). The possibility that students are gaining academically relevant knowledge but in a very one-sided way, and with misconceptions also being common, is of concern to their future academic careers as well as to their understandings for future life decisions. As demonstrated in the findings, the mass media currently only portrays part of the story. In Chapter 1 I expressed a hope that the findings of this research might persuade media to present genetic science in the most conceptually appropriate way. In Chapter 2 I discussed Dhingra's (2012) explanation of entertainment education (EE) in which persuasion campaign messages are embedded into TV shows with some success. Consequently, it may not be too much to hope that the findings of this research may be able to encourage TV show writers to portray more of the biological nature and function of DNA within their storylines. Nonetheless, the primary role of entertainment mass media is not to instruct but to entertain, so 'blame' is unproductive. Further, it would seem likely that most primary students would know little genetics without the mass media, and TV shows raise interest in aspects of science. Even if more complete science was included in TV storylines, this would be no substitute for sound teaching at school. Giving students' 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.

I further contend that for students to become scientifically literate adult 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 nonscience. 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.

This thesis opened with personal reflections upon my background and career that led to the interest and desire to explore this topic. Before I began, even before I had

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finalised the specific topic, I noted my strengths for and expectations of doctoral research. I found it relatively easy to see how the various threads of my life and my career had led me to this endeavour, and given me the skills and circumstances to make the most of this opportunity. Looking back, I realise I was remarkably astute about both my strengths, and my expectations, and this self-knowledge may well have been the greatest key to my success. This doctoral research has been a fascinating learning journey, in which, as I foreshadowed, many existing skills have been refined and honed, and new knowledge and skills acquired.

To sum up, I have chosen to close with recent words from Australia's Chief Scientist, Professor Ian Chubb. I wholeheartedly agree with his statement and seek to do further research in one or more of the areas outlined in this chapter, 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)

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Table A1.

Specific genetics topics and their appearance in Australian state and territory curricula and syllabus documents.

Genetics topic	State/Territory	School Year level
Cells	New South Wales	7-8
	Victoria	7-8
	Queensland	7
	South Australia	8-10
	Australian Capital Territory	8-9
	Tasmania	5-6
	Western Australia	7
	Draft National Curriculum	8
DNA	New South Wales	9-10
	Victoria	9
	Tasmania	9-10
	Western Australia	10
	Draft National Curriculum	10
Genes	New South Wales	9-10
	Victoria	9
	Queensland	9
	Tasmania	9-10
	Western Australia	10
	Draft National Curriculum	10
Chromosomes	New South Wales	9-10
	Queensland	9
	Western Australia	10
	Draft National Curriculum	10
Dominance and recessiveness	South Australia	10
	Tasmania	9-10
	Western Australia	10 extension only
Genotype and phenotype	Western Australia	10 extension only
Genes and patterns of inheritance	Victoria	9
	Tasmania	9-10
	Draft National Curriculum	10
Mendelian inheritance	Victoria	9
	Western Australia	10
Monohybrid crosses	South Australia	10
	Tasmania	9-10
	Western Australia	10 extension only

Punnet squares/pedigrees	South Australia	10
	Tasmania	9-10
	Western Australia	10 extension only
Inheritance mechanisms such as independent assortment, incomplete dominance	New South Wales	9-10
Mitosis and Meiosis	New South Wales	9-10
	Victoria	9
	Western Australia	10
Genes and chemical processes	Draft National Curriculum	10
DNA replication, mutation & translation into proteins	New South Wales	9-10
	Western Australia (mutations only)	10 extension only
Interaction of genes and environment	New South Wales	9-10
Human genetics	South Australia	10
	Tasmania	9-10
Gene technology/issues	New South Wales	9-10
	South Australia	10
	Tasmania	9-10
	Western Australia	9-10

Note. As these documents change regularly, below are the reference citations for the specific versions of curricula and syllabus documents surveyed in November 2010.

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Table A2.

Known genetics misconceptions held by many students, scientific conceptions, and the researchers who identified these misconceptions.

No.	Misconception	Scientific Conception	Identifying Researchers
1	That genes and DNA are two totally different things i.e. no understanding of the *structural* relationship between genes and DNA	Genes are made of DNA, at the simplest level, they are sections of DNA with a specific function	Berthelsen (1999); Lestz (2008); Lewis and Kattman (2004); Lewis and Wood-Robinson (2000); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Venville, Gribble, and Donovan (2005, 2006)
2	That genes are what make you resemble your family, whereas DNA is what makes you unique and identifiable, primarily as a prime suspect i.e. no understanding of the *functional* relationship between genes and DNA	As genes are made of DNA, **both** are involved in making you resemble your family, and in making you unique and identifiable. You inherit specific alleles (forms of genes) from your parents so you will resemble them. However, due to processes in meiosis that create the sex cells, you inherit a unique mix of these alleles. That makes you uniquely identifiable (unless you have an identical twin)	Donovan and Venville (2004); Lewis and Kattman (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Venville, Gribble, and Donovan (2005, 2006)
3	That DNA does not have a biological function, it is just there to be shed at crime scenes	DNA has important functions in that it controls and manages all cellular operations through coding for specific proteins	Donovan and Venville (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Venville, Gribble, and Donovan (2005, 2006)
4	That DNA is only found on the outside of the body (skin, hair, fingerprints) and in the blood (possibly only in the left arm)	DNA is found in nearly all cells of the body (exception is mature red blood cells)	Donovan and Venville (2004); Lestz (2008)
5	That DNA can be found in some nonliving things (e.g. cars) but might not be in some living things such as plants, fungi and microorganisms	DNA is NOT found in nonliving things, but IS found in all living things, including plants, fungi and microorganisms	Donovan and Venville (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Venville, Gribble, and Donovan (2006)
6	That genes are the characteristics or traits themselves (e.g. floppy ears on a dog is a gene)	Genes contain the code for characteristics, they are not the actual characteristic	Lewis and Kattman (2004); Venville, Gribble, and Donovan (2006)

7	That a gene makes a specific body part (e.g. hands) also seen in the belief that humans inherit a gene for 'tall' just as Mendel's pea plants did	Complex organs result from many genes acting together, and in humans, height results from the interplay of several genes and the environment such as nutrition	Donovan and Venville (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Wood (1993)
8	That particular genes are found only where they are expressed (so nerve cells would contain different genes from cheek cells) i.e. they are deducing genotype from phenotype at cell level	All but a few cells in the body contain all of the genes. Cells are different because different genes are switched on or off. Genotype operates at cell level, phenotype operates at whole organism level	Lestz (2008); Lewis and Kattman (2004); Venville, Gribble, and Donovan (2006); Wood (1993)
9	That single genes exist 'for' particular traits (e.g. for fat legs, or chemical dependency) i.e. the student holds deterministic beliefs	Genes interact in complex ways to produce some characteristics, there is no one gene for most traits	Lewis and Kattman (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Venville and Donovan (2005c)
10	That heredity is the transfer of discrete and unchanging trait-bearing particles i.e. the perpetuation of genes and traits	Heredity is the transfer of genes which may be changed by mutation and are reassorted by meiosis and fertilisation	Donovan and Venville (2004); Lestz (2008); Lewis and Kattman (2004); Venville and Treagust (1998); Wood (1993)
11	That a trait that appears in one generation must have existed in at least one of the forerunning generations, they are 'hidden' traits	This is a poor explanation of recessive alleles, which will only show up if an individual inherits two of them i.e. from both parents	Lewis and Kattman (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008)
12	Ascribe vague or inappropriate biological functions to genes (such as controlling blood sugar), which occur by unknown mechanisms.	DNA code in genes causes the production of specific proteins that do the work of the genes and produce the characteristic. All genes do not control blood sugar, only some genes produce the hormones that exert this control	Chattopadhyay and Mahajan (2004); Donovan and Venville (2004); Duncan and Reiser (2007); Lestz (2008); Lewis and Kattman (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008)
13	Cannot distinguish between gene and 'genetic information'	The gene is the complex entity, the genetic information is the DNA code	Chattopadhyay and Mahajan (2004); Donovan and Venville (2004); Lestz (2008); Lewis and Kattman (2004); Wood (1993)
14	Cannot distinguish between genotype and phenotype	Genotype is all the alleles (forms of genes) that an organism has, phenotype (appearance) results from the interplay of those alleles in the specific environment	Donovan and Venville (2004); Lewis and Kattman (2004); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Wood (1993)

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15	Cannot associate genes with proteins or explain gene products	Genes cause the production of specific proteins which do the work	Chattopadhyay and Mahajan (2004); Donovan and Venville (2004); Lewis and Kattman (2004); Marbach-Ad and Stavy (2000); Wood (1993)
16	That genes exist only to cause disease, especially in babies, i.e. holds deterministic beliefs	Genes have important functions to make us normal, only incorrect versions of genes may cause disease	Mills Shaw, Van Horne, Zhang, and Boughman (2008); Venville, Gribble, and Donovan (2006)
17	That all chromosomes are either X or Y	There are 22 pairs of non-sex chromosomes (autosomes) and only one pair of sex chromosomes, XX in females and XY in males	Lewis and Kattman (2004)
18	That girls get more DNA (or genes, chromosomes, genetic information) from their mothers and boys get more from their fathers (inaccurate vocabulary)	Boys and girls both get all 22 autosomes equally from both parents, boys get slightly less chromosomal material overall as the Y is smaller than the X chromosome	Engel Clough and Wood-Robinson (1985); Berthelsen (1999); Lewis and Kattman (2004); Wood (1993)
19	That genetic information (or chromosomes) are not copied before being shared out, or cannot explain conditions resulting from abnormal chromosome numbers. They may think that offspring have a complete extra set of chromosomes	The DNA is first copied to form duplicate structures called chromosomes, which are then split in half and shared between the new cells resulting from cell division. Sometimes an error results in an offspring having 1 extra chromosome	Lewis and Kattman (2004); Lewis and Wood-Robinson (2000); Mills Shaw, Van Horne, Zhang, and Boughman (2008); Wood (1993)
20	That information from mothers and fathers may be differentially expressed (e.g. you might look like your Mum on the outside so that means your organs on the inside must run like your Dad's)	Both the alleles from Mum and Dad may contribute equally to all attributes or traits that are genetically controlled. Genes also don't work in isolation.	Mills Shaw, Van Horne, Zhang, and Boughman (2008); Wood (1993)
21	Cannot represent accurately the chances of inheriting alleles in dominant and recessive traits (e.g. stating that if neither parent has/carries a recessive gene, there is a 25% chance of a child having the trait)	If neither parent carries the recessive allele, a child with the disease must have arisen by a new mutation in BOTH alleles (i.e. from both parents) which would be extremely rare, much less than 25%	Mills Shaw, Van Horne, Zhang, and Boughman (2008)

22	That the term hereditary is equivalent to a trait having a genetic component	Most diseases have a genetic component without being hereditary – difference between inheriting a predisposition and the actual disease	Mills Shaw, Van Horne, Zhang, and Boughman (2008)
23	That eugenics (practice of 'improving' the human race by deliberate design) is the main goal of genetic research	This is not reflective of the goals or ongoing work of genetics research	Mills Shaw, Van Horne, Zhang, and Boughman (2008)
24	That a single genetic discovery will provide a cure for most diseases	At best, a single discovery might help cure one genetic disease	Mills Shaw, Van Horne, Zhang, and Boughman (2008)

Note. Different studies asked different questions, and provided varying opportunities for the participants to mention some aspects of genetics, so not all misconceptions are reported universally. Different researchers worked with different ages and background experience of participants in different countries. The various reported works of Donovan, Gribble and Venville, collectively examined the misconceptions of Australian students from Years 2-10, i.e. from ages 7-15, whereas Wood (1993) worked with similarly aged New Zealand children. Lewis and her colleagues focused on English and German students aged 14-19. Lestz (2008) reported on American college students and Mills Shaw, Van Horne, Zhang, and Boughman (2008), analysed the genetics essays of over 2000 American high school students. Chattopadhyay and Mahajan (2004) reported the responses of undergraduate biotechnology students in India, expected to have very detailed knowledge. Cardak and Dikmenli (2008) repeated Chattopadhyay and Mahajan's study with pre-service science teachers in Turkey with very similar results (not included in Table A2).

Appendix B. Research Instruments

B1- Media Questionnaire p. 1

MEDIA QUESTIONNAIRE FOR YEAR _____ at _____ SCHOOL

1. TICK (✓) the box that is your BEST answer for each part of this question

Qn 1	How often do you	Every day	2-3 times a week	Once a week	Every 2 weeks	Once a month	1 every 2-3 months	Once a year	Never
A	Read comics?								
B	Watch TV?								
C	Use the Internet?								
D	Look in a newspaper?								
E	Listen to radio?								
F	Look at a magazine?								
G	Play an electronic game?								
H	Go to the movies?								

2. TICK (✓) the box that is your BEST answer for each part of this question

Qn 2	What would be the USUAL amount of time you spend EACH time you	Less than 1 hour	Between 1 and 2 hours	Between 2 and 3 hours	Between 3 and 4 hours	Between 4 and 5 hours	More than 5 hours
A	Read comics?						
B	Watch TV?						
C	Use the Internet?						
D	Look in a newspaper?						
E	Listen to radio?						
F	Look at a magazine?						
G	Play an electronic game?						
H	Go to the movies?						

3. Write your answers in the boxes for this question, up to 3 favourites for each of A to H categories

Qn 3	What are your favourite or usual	Favourite 1.	Favourite 2.	Favourite 3.
A	Comics you read?			
B	TV shows you watch?			
C	Types of sites you visit on the Internet?			
D	Newspaper you look at?			
E	Radio stations you listen to?			
F	Magazines you look at?			
G	Electronic games you play?			
H	Movies you've seen?			

4. From the SAME TV shows that you said were your favourites in Q3, name up to 2 favourite characters in the boxes below

Qn 4	Who are your favourite characters in TV shows?	Favourite Show 1	Favourite Show 2	Favourite Show 3
	Character 1			
	Character 2			

PLEASE TURN OVER THE PAGE TO ANSWER THE REST OF THE SURVEY

5. 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?

TICK (✓) the box that is your BEST answer for each part of this question

	Yes, every week	Yes, most weeks	Yes, a few times	Yes but only once or twice	No, never watched this	Like or Dislike (Write L for like D for dislike if you've seen the show)	Write character's name or say what they do in the show (Favourite Character if you have one)
A CSI/ CSI: Miami/ CSI: New York (any or all)							
B NCIS							
C Bones							
D Without a Trace							
E Cold Case							
F Find My Family							
G Who Do You Think You Are?							
H Can We Help?							
I The Mentalist							
J Law and Order							
K Insight							
L Weird Science							

6. In your house, which TV stations are most watched by your family?

Number the channels 1, 2, 3 etc with 1 as the MOST watched, don't number a channel you don't have or watch

ABC 1	ABC 2	Channel 7	Channel 9/WIN	Channel 10	SBS	HD channels	Foxtel/ Aus-sat channels	Other

NOW PLEASE FILL IN THIS INFORMATION ABOUT YOU, AND THEN YOU'RE DONE! THANK YOU!

Your first name e.g. Peter, Jane	Your date of birth e.g. 21 July 2000			In which country were you born?	What time do you usually	Get up in the morning?	Go to bed at night?
	DAY (number)	MONTH (word)	YEAR				

The first letter ONLY of your last name e.g. for Adams, just write A

What language(s) do you speak at home?

Tick (✓) the right box to show that you're a

BOY ( ) or a GIRL ( )

Which best describes where you live? Tick (✓) the box.	
In a suburb with lots of houses nearby	
In a country area with a few houses nearby	
On a farm or property with no houses near	

INTERVIEW PROTOCOL

NB: Parts 1 and 2 are tested questions from earlier research. Part 3 consists of new questions for this specific research.

Part 1
Aim: to determine if interviewee understands how and why offspring resemble their parents. i.e. to probe for a genetic theory that the interviewee differentiates between the visible characteristics (phenotype) and the microscopic (abstract) causal mechanisms such as genes, DNA or chromosomes (genotype).

Interviewer shows interviewee several pictures of adult cats and kittens.
(NB: We changed from dogs and puppies to cats and kittens in the previous research to avoid sensitivities of Islamic children)

<u>Question 1</u>: **What do you notice about these photographs of cats?** (Let the students talk about the photographs, but encourage them to notice that some are adult cats and some are kittens.)

<u>Question 2</u>: **Do you think any of the adult cats are the parents of some of the kittens?**
If yes: Go to Q.3   If no: Why not?

<u>Question 3</u>: **Which adult cats and kittens do you think belong together as parents and babies/children?** When they point some out, note down which ones they selected and ask: **Why do you think so?** (Probe: because they look alike, they have similar features; they have the same colour fur etc.)

<u>Question 4</u>: **Do you know why/what makes the kittens often look similar to the parent cats?** (Probe for genes, chromosomes or DNA. Student may have their own idea about a mechanism for inheritance. Alternatively they might have an idea but not the language e.g. some 'thing' goes from the parent to the baby. Get them to elaborate on their ideas as much as possible, e.g. tell me more about that?)

If students are able to talk about genes, DNA or chromosomes or some other abstract entity that is different from the characteristics themselves then go on to part 2.

If they have not mentioned these things then ask them if they have heard of genes, DNA or chromosomes and get them to tell you what they know about them and then go on to part 2.

If they have never heard of these things at all then reassure them it's OK not to know and terminate interview here.

Part 2
Aim: To determine interviewee's conception of the means of genetic inheritance.

<u>Question 5:</u> You mentioned genes/chromosomes/ DNA – use student's words.
Do you think humans have genes/DNA chromosomes too?

If yes: go to Question 6.   If no: why not?

<u>Question 6:</u> **Where do you think genes/DNA/chromosomes are in the body?**

<u>Question 7:</u> **What do you think genes/DNA/chromosomes look like?**

<u>Question 8:</u> **What do you think genes/DNA/chromosomes do?** (Probe for understandings of what they do in the human body, such as determining features, causing diseases etc. If they mention crime, forensics etc, write their answers in under Q.12, then return to probe this question).

<u>Question 9:</u> **How do you think genes/DNA/chromosomes work?** i.e. What do genes do to make people look the way they do and have the characteristics they have, for example red hair, colour blindness? (Probe that they are like a 'recipe' or 'instructions' for the body etc. further that they produce proteins.)

<u>Question 10:</u> **What do you think is the same or different about genes and DNA/chromosomes?** (Probe if student understands that they are essentially the same thing.)

Part 3
Aim: To determine the source(s) of the interviewee's knowledge about genetic materials.

<u>Question 11:</u> **Where did you hear about genes/DNA/chromosomes?** (Probe for parents, classroom, media sources. If they mention media such as TV, ask them to be more specific about TV shows, news etc)

<u>Question 12:</u> **Can you tell me more about what genes/DNA/chromosomes are used for? Where did you learn about that?** (Probe for relationship to crime-solving, paternity testing etc).

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

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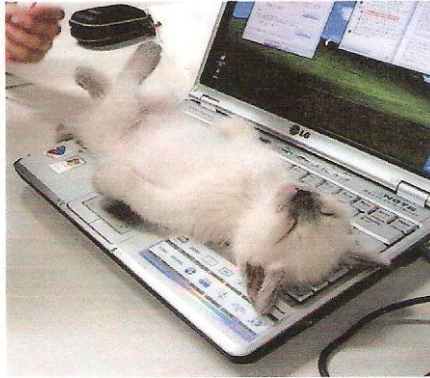
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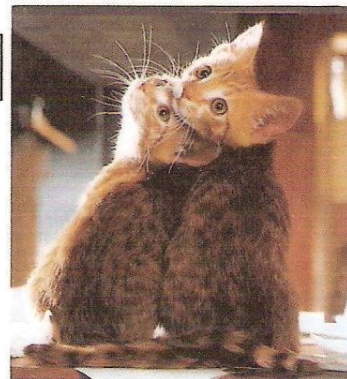
B4 - Interview Record Sheet and Answers

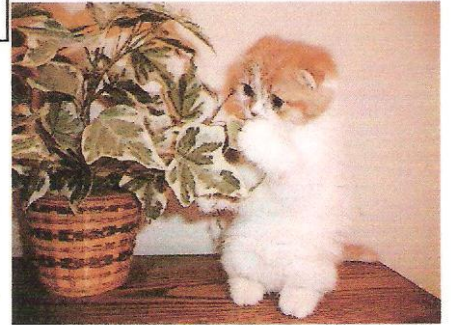| QN	What they can do	Yes/No	Comments	Score
1	Observes some are adults and others kittens without help	Y N	Sensible reason	**1** 0
2	Recognises some adult cats and kittens are related	Y N	Sensible reason	**1** 0
3	Which cat/kittens selected?	2 combos 1 combo 0 combo	Suitable combos are 1 & 6, 2 & 14, 3 & 12, 4 & 11, 7 & 10, 8 & 15, 9 & 13. NB 16 is a pair of kittens so not the best to say 1 adult, 1 kitten.	**2** 1 0
	Why do they think they're related?	2 features 1 feature 0	Look alike, same colour, same pattern of fur, same length of fur, same breed, same shape face, same eye colour etc	**2** 1 0
4	What makes kittens look similar to adult cats?		Mention of genes/DNA/chromosomes Something passed down from parents	**2** 1 0
	Mentions genes, chromosomes or DNA spontaneously Has heard of them when mentioned by interviewer		Spontaneous of genes/DNA/chromosomes (may be recorded in space above) Prompted answer	**2** 1
	Spontaneous knowledge of genes/DNA/chromosomes		Both genes and DNA passed from adult to baby, make you who you are etc. Give 1 for partial fact eg DNA in fingerprints	**2** 1 0
	SUBTOTAL PART 1			**12**
5	Knows humans have genes/DNA/chromosomes	Y N	Mentions both DNA and genes Either	**2** 1 0
6	Where they think genes/DNA/chromosomes are located		All cells/everywhere in body Lists some parts of body No idea	**2** ½ ea 0
7	What they think genes/DNA/chromosomes look like		Mentions spiral/double helix/genes joined end to end Microscopic	**2** 1 0
8	What they think genes/DNA/chromosomes do		Determine features, control how body is made Cause diseases	**2** 1 0
9	How they think genes/DNA/chromosomes work in body		Produce proteins that make up the body Recipe/instructions that tells how to make up the features	**2** 1 0
10	What they think is similar/different about genes & DNA	Similar	Genes are made of DNA Both come from parents & help make features	**2** 1 0
	SUBTOTAL PART 2			**12**
11	Where did they hear about genes/DNA/chromosomes?	Parents	Give 1 for each source mentioned	
		School		**3 max**
		Reading		
		TV		
		Other		
12	What else are genes/DNA/chromosomes used for?	Crime	Give 1 for each use mentioned	
		Forensics		**3 max**
		Paternity		
		Diagnosis		
		Other		
	SUBTOTAL PART 3			**6**
	TOTAL INTERVIEW SCORE			**30**

Appendix C. Forms

C1 – Parental Information Sheet

THE UNIVERSITY OF WESTERN AUSTRALIA
Achieving International Excellence

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CRICOS Provider Code: 00126G

PARTICIPANT INFORMATION SHEET
RESEARCH PROJECT: THE IMPACT OF THE MEDIA ON STUDENTS' UNDERSTANDINGS OF GENES AND DNA

Dear Parent/Guardian,

This note is to inform you about a small research project that will be conducted in your child's school this term and may involve your child. The purpose of the research is to find out whether the way genes and DNA are presented in the media (such as newspapers and TV) influence the understandings that children have about these important topics.
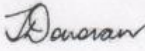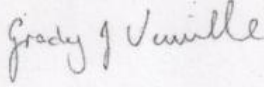
The procedure will involve children firstly completing a written survey about their exposure to the media, and then possibly being interviewed or otherwise asked about their understanding of what genes and DNA are and do. Please do not talk to your child about these topics prior to the interview as it is their everyday understandings that we are interested in. Interviews are expected to take between 10 and 15 minutes and will be tape-recorded. The information collected may be used by researchers and the teacher to help improve the teaching of these topics but it will NOT be used to contribute to your child's marks or grades. We have found in the past that children generally respond very well to being interviewed and this process improves their learning. Data from several schools will be compiled to establish patterns and trends and later published. However, children, teachers and schools will NOT be identified in reports.

The interviewer is a qualified and experienced teacher and researcher with experience working with and interviewing school-aged children. She also has police clearance to work with school students.

We have been given permission from the Principal, and your child's teacher, _____, to conduct the research in the school. The research also has been approved by the Human Research Ethics Committee at the University of Western Australia.

Your child's participation in this research is voluntary. You can give permission for your child to participate in the research by signing the consent form on the following page and returning it to school. Your child should also sign this form and can choose to withdraw from the research at any time. The Human Research Ethics Committee at the University of Western Australia requires that all participants are informed that, if they have any complaint regarding the manner in which a research project is conducted, it may be given to the researcher or, alternatively to the Secretary, Human Research Ethics Committee, Registrar's Office, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009 (telephone number (08) 6488-3703). Please keep this copy of the Information Sheet for your personal records. A copy of the Consent Form will be given to your child to be returned to you.

Yours faithfully

Grady J Venville

J Donovan

Supervisor: Prof. Grady Venville

Phone: (08) 6488 3811
Email: grady.venville@uwa.edu.au

Researcher: Jenny Donovan

Phone: 0405 336 515
Email: jenny-donovan@hotmail.com

PARENT/GUARDIAN CONSENT FORM

RESEARCH PROJECT: THE IMPACT OF THE MEDIA ON STUDENTS' UNDERSTANDINGS OF GENES & DNA

PLEASE READ THE PARTICIPANT INFORMATION, SIGN AND RETURN this

form back to the school by _____.

THANK YOU

I _____ (full name of parent/guardian) have read the participant information sheet and give

permission for my child _____(child's full name) to participate in the research project called The

Impact of the Media on Students' Understanding of Genes and DNA. I understand that my child's participation is voluntary and

that my child can withdraw at any time in which case their information will be returned or destroyed. I understand that all

information provided is strictly confidential and will not be released by the investigator. I have been advised as to what data is

being collected, what the purpose is, and what will be done with the data upon completion of the research. I agree that research

data gathered for the study may be published provided my child's name or other identifying information is not used.

_____   _____

(Parent/guardian signature)   (Date)

STUDENT CONSENT FORM

RESEARCH PROJECT: THE IMPACT OF THE MEDIA ON STUDENTS' UNDERSTANDINGS OF GENES & DNA

I _____ (full name) agree to participate in the research project called The Impact of the Media

on Students' Understanding of Genes and DNA. I understand that I will be asked questions about how often I look at media such

as TV and newspapers. I also realise that I may be interviewed or asked questions about whether I have heard of genes and DNA.

I know I can choose to be involved in this research or to stop at any time.

_____   _____

(Student's signature)   (Date)

The Human Research Ethics Committee at the University of Western Australia requires that all participants are
informed that, if they have any complaint regarding the manner in which a research project is conducted, it may be
given to the researcher or, alternatively to the Secretary, Human Research Ethics Committee, Registrar's Office,
University of Western Australia, 35 Stirling Highway, Crawley, WA 6009 (telephone number (08) 6488-3703). All
study participants will be provided with a copy of the Information Sheet and Consent Form for their personal records.

Appendix D. Student Statements about Genes and DNA

Table D1 shows each interviewed student's statements about DNA. These were combined from the answers to various interview questions, and are generally verbatim but with repetitive utterances such as "ah" and "um" removed, and occasional linking words added to enhance clarity. Where the student's comments were used as a student statement in Chapter 5, the statement number is shown. Shading indicates year group.

Table D1

Student statements about genes and DNA (G=Girl, B=Boy) and reference number if used in Chapter 5

Sample	Year	Sex	Name	Statement	Number
1 Above average SES Qld Free access to all TV channels	5	G	Theresa	DNA is like a gene that goes into their body when they are born. DNA is in the skin, both DNA and genes are in blood. Parents give some DNA and genes to you to look like them, but also to tell them apart. DNA looks like a white fluid – I've seen it on TV – I can't remember more but I know it's white. I'm really interested in medical shows and crime shows, though I don't watch those listed, I watch others. I know they use DNA to find out who the criminal is and keep them in jail so nothing else bad will happen.	13
		B	Tobias	I know that they're doing research with DNA, taking DNA out of dinosaur bones and putting it in like rats and mice. Because then, hopefully when they breed them, that dinosaur DNA will pass on and will probably start getting the effects that the dinosaurs would look like, to find out more about them. I'm not sure where DNA is ... bones, blood. I'm not sure, I think it's just ... it makes you who you are, makes you different. Different from other people. It's from your past relatives. I heard about DNA on the *News*, from my parents, I know that on *Bones* they use it. I know that they can use it ... there's technology now, you can get the bones, get the DNA, do a special scan and actually find out what the person looks like. I, if you like touch something, or you're cut, it goes onto something else, you might be able to pick up the DNA there and find out a bit about you. Maybe it's in the blood and other liquids in the body, like the liquid in scabs, pus, as well.	
		B	Cory	Genes control thinking and attitude. Genes mean I have the same hair colour as Dad, and the same abilities like swimming. Genes could	

				have DNA. I learned more about DNA on documentaries but also from the detectives on *NCIS*. DNA is about identity, it makes you who you are.	
		G	Anne	I've only heard of DNA, it's in blood and fingerprints. I saw it on *Bones* – we only use DNA to find parents. We use it to find people, to find the parents of children. I saw it on *Medical Emergency* show, and on *Bones*, if they find skeletons, dead people, they can find out who they are.	
		G	Katrina	DNA is only in the fingers and tongue. It's to identify who's who, who's your father. Can use DNA if a person wants to find out whose baby it is. It can be used to solve murder cases – Abby uses it (on *NCIS*) to find people. I've seen about DNA on *Find My Family* and on *Bones* as well.	
		B	Joel	If someone broke into a car, you can put a special powder over it, it shows up the fingerprints, then you get the DNA. I know because my Auntie's car was fingerprinted. And I've seen it before on *CSI,* I watch it with Mum but I'm not really watching it. DNA is only in the hands and feet.	5
	6	B	Prasai	When the kittens are in the womb . . . I think it's like when the mother eats food and it is transferred to the kittens, I think genes and DNA are transferred into them too. Genes come from mother's mother and mother's father, and kind of merged into one gene. A kitten is a mix of the father and mother of the kitten. It's the same for humans. DNA is everywhere, blood, bones, brain I think, cells. Genes are bubbly, joining together, but DNA is a spiral staircase, I've seen a model. DNA is information. You have DNA from a mix of your parents' DNA, which tells how you should look. Identical twins have the same DNA. DNA can tell you how you look ... same for genes ... makes you look a bit like you. Ummm ... kind of similar, DNA, I think it kind of tells us what the person will look like, and genes are from your family relations and are passed down. I learned about DNA in my school in Malaysia in Years 1 and 2. I've also done my own research into it, I got interested, and used the Internet. I know police use DNA, and scientists do experiments to find more purposes of DNA. Well, you can take fingerprints, that's a DNA sample. You can use genes to find the family. To identify people, scientists could use a very technical, advanced computer, and get samples of DNA	

				that might be on fingerprints, and use the computer to find out how the person looks like.	
		G	Elaine	My friend's father is a policeman, he works with DNA. He uses it to catch bad people, to find people if they've been bad. Fingerprints have DNA, it's everywhere, it's the patterns on your fingerprints. I saw it a little bit on TV, on the *News* and a bit on *Find My Family* though I don't like that show much.	
		G	Katherine	When kittens are born they just get genes from their parents, passed down. DNA tells you if you're related I think. Genes are in blood and maybe the skin, but DNA is only in the blood. Both show your body or personality. I've seen about it on science shows and other people talk about it. We don't really use DNA, we just have it.	
		B	Willis	Genes and DNA get passed through the adult mother to the baby. Pretty much everything has genes and DNA, even trees, because seeds and all that, they'll probably grow into the same type of plant. DNA is from your hair, spit, oil that comes from your skin, your fingerprints. Maybe in your ears, the wax might contain DNA or something, I'm not sure. And your organs probably would contain DNA. I think genes are like ... shaped like ... long curly shapes, and they're connected like a rope. And DNA ... (long pause) ... (mutters to self – now what would DNA look like?) No I don't know what DNA looks like, I know it's in hair and stuff. (Interviewer mentions chromosomes). Yes, chromosomes, I've heard of that. Yep, that's what I mean by connected like a rope. If we didn't have genes and DNA, you and I would probably look the same. It gives us different ways to look. If we all had the same genes we'd probably all look the same. Genes and DNA are similar, mostly, just a little bit different. They have the same sort of effects, like, police people can probably use genes **and** DNA to work together to find like a person. Genes are the ones that make you look different from other people, and DNA is the thing that gives off things – like if you get *my* hair you can tell that it's *my* DNA ... but I'm not that sure. I learned about DNA from books, programmes, and just from going on the Internet, from DNA books, there are books about DNA. From DVDs, like DNA of the human evolution ruler – how it changes from gorillas all the way through to humans. I know *Catalyst* has some things on DNA and all that. Oh, yes, on *Can We Help?* It goes right to the scene when they think they've found people,	10

				and they take DNA and see if they can match it. And like if I was on Google, I just type like DNA or genes into the search box and it comes up with loads of sites, full of lots of words that I cannot pronounce. Like what DNA stands for, I still cannot pronounce. Can use DNA to help find people, families. Also, if there's a criminal, a crime scene, they can ... a tiny hair follicle you know can be looked at under the microscope and they can find all the DNA. It means it must be very small. And there must be lots of different types, from your fingers, your hair, and all that. For crimes they like ... if you left like your hat, there's pretty much a 99% chance that there's going to be like hair or skin cells or sweat that they can use to find the DNA. Then, well if it's a criminal who did it, they'll probably log it into the computer and then the computer will come up with all these subjects and the DNA will give you maybe one or two people who might have a direct match. Also, can use DNA to help diseases. So like if you have cancer in one of your organs, they can take a tiny bit of your organ, freeze it, and then slice it into thin slices and put it under the microscope and then they can see if it has cancer in it, or anything else. Can see if the DNA looks right or not.	
		B	Neil	Genes make you related, in the same family, you might have the same colour eyes as Mum. If you're a boy, your Dad gives his Y gene and your Mum gives her X gene. If both of them have blue eyes, so will you. DNA makes you different from other people. If a criminal commits a crime, leaves a fingerprint or another DNA sample like blood or spit, police can tell them apart from other people. DNA is also in skin and urine. It's the little pattern on your fingers, which grow as you grow. When DNA's in saliva, if you're sick, it's yellow. Crime, like I said before, and like, on *Find My Family*, if people move away, can find them with a DNA sample. I've seen it on the *News*, *CSI, Find My Family, Law & Order, The Mentalist* (a bit) and on *Blue Heelers* too.	2
		G	Skyla	A bit of both parents' DNA goes into the kitten sometimes, but it could just be from one parent. I got Dad's genes for eyes, but Mum's nose - genes could come from either parent or both. DNA is used to identify you, it's in hair, fingerprints and blood. Genes are what your parents give you, DNA identifies you, it's part of you. For crime, you can analyse hair or fingerprint to find a person. I've seen that on *NCIS*, though there's not much in that show	

				about eyes. In forensics, you can use DNA to find who has stolen something.	
	7	B	Bennett	We get our parents' genes, but DNA, everyone's got different DNA. It's in the stomach, brain, heart, skin, and some cells. Everyone's got different DNA but some genes are the same. I saw it on *CSI* and on documentaries. Can use DNA to find out who did the crime. Can use fingerprints, hair. Can also use DNA to identify people who died in wars.	
		G	Madeleine	We get genes from our parents to look similar, but DNA tells you apart from everyone else. DNA's in the blood and brain. I don't know much about it. It makes you look as you do. I've seen it on the *News*. Can use DNA for crime, to find out who did it. I think Doctors use it in surgery too, but I'm not sure.	
		G	Annette	Genes are like the cells that your parents basically give to you when your Mum's pregnant. They're little cells from the parents, so yeah like, the sperm and the egg will both have the genes, or cells inside them, and that would determine what colour of fur it has, what its face will look like and all that sort of stuff. The chromosomes are what the parents give to you, which makes up your genes, and your DNA also comes from your parents, it's similar, but it's still unique, but it's given to you. And because the two different ones, when they bond together they won't be exactly the same, they'll make another different one again. They're all throughout your body, in the cells that make you up. Well no one can really determine the cells, because they're so small you can't see them, but if you look really close, like a powerful microscope, you might be able to see them, but I've not seen them yet on TV or in person or anything. The chromosomes and the DNA I heard about in health, also some of it I learned from my parents, like if I watched a certain TV show and it might have spoken about some things I don't understand, like genes, or something, I might have asked them and they explained it all to me. I usually don't go to bed until about 10 o'clock, so usually the later night shows, on *NCIS*, and *Law & Order* a little bit. Oh and I've heard about it on the *News* too, when I was younger. DNA can also be used for like tracking a criminal, like, for example, there's bits of hair left on ... or something they tried to steal or something ... They use a special machine, and the machine will determine if it knows the DNA or if it's used that DNA	11

				before, and it will also show what the DNA looks like so you can compare it with other DNAs and find a culprit. We can also use DNA like these days, they've come up with how to clone things, like cloning pets.	
		B	Macey	They don't get their parents DNA, they get their own DNA, but they get their genes from their parents. That saliva has DNA and it's all in the blood and everywhere I think. But genes, you get them from your parents when you're in the uterus. Genes are in your features, like your facial features. Friends say you look like your Dad because of your genes. That's what my Aunties say, and my friends and their Mums. Genes are invisible, they're microscopic. Your genes are like your features and your DNA is like ... like ... I'm trying to think of the word ... it's like ... um ... DNA is like what's on the inside of you, yeah, in the inside of you, like skin follicles and all that. And then DNA, I heard um like cop shows and all that. *NCIS*, *Bones* and the *News*. I like Abby on *NCIS*. Can use DNA to catch the criminal. Use a special white powder on the fingerprints or blood, and then they do a process in a machine or something and find the person.	12
		B	Branson	I think genes are what might make kittens similar to adults. I know that DNA is in blood samples, but genes are things you get from your parents. DNA gives you similar looks or character. I know both genes and DNA come from your parents. I learned about DNA on science TV shows like *CSI*. Mum watches them. Not sure about the others, but definitely on *CSI*. On *CSI* they use DNA to see who did it and find what they look like.	
		G	Shanee	DNA is the stuff that makes you you, Mum's and Dad's DNA was put together to make me. DNA is in skin, fingerprints – it makes them unique – also in hair samples and the bloodstream. It's very minute, you need a microscope to see it. It makes the features. I learned about DNA mostly on *Bones* and *NCIS*, not so much on *The Mentalist*, and not much on the *News*. If criminals leave a hair sample, we can computer match their DNA. Police put DNA records onto a computer. Can also use DNA to find parents of adopted people. I think DNA can also be used to diagnose breast cancer and diabetes.	9
2 Average SES	5	G	Tara	I've only heard of DNA, they find victims with DNA, and find out who's the father. DNA is in the cells, nearly every cell. I've learned about it on kids science shows, maybe the *News* too.	

SA		G	Geraldine	Can use DNA to find evidence at crimes. DNA can tell who you're related to. I don't know much about genes. I think DNA's in the wrist but I'm not sure. I've read it in science books, seen it on *Insight* and on the *News* sometimes. That's all I know.	
New school					
Area lacks free access to Channel 9 (*CSI, Cold Case, The Mentalist, Without a Trace*)		B	Benny	Two kittens have exactly the same fur, probably because they've both got the same DNA. Every related person has the same DNA, but an adult may have more DNA than a child, like I got my DNA from Mum only. People who are not sure if they're related or not can use DNA to find out. Can also use it to solve crime – like at a car crash, because of alcohol, can get the blood, but it might be too long after the crash to get evidence. I've seen that on *Highway Patrol* and *Recruits* on TV. DNA is the blood, it travels around the body in 1 minute, the heart pumps it, I've been told it's blue when inside the body, but goes red when it hits air. It keeps the organs running and we can donate DNA to those who need it. I've had DNA tests done, the Doctor took my blood to test for allergies.	
		B	Carsten	I reckon they take DNA from their own body and then they put it onto the little chick, or kitten or pup, that's still in their belly and then when it comes out, after a while it starts producing the same colour. Genes are like boy and girl. DNA is like a sample, like with the cat, like a piece of skin, a piece of fur, a vessel. DNA starts off as one person in the world, and then if it's a girl it might go to another girl, then it might multiply and multiply and multiply and multiply, and then from the first girl, that DNA goes into the next person, the next two, and then they might have a boy and a girl and then ... I got my DNA from my Mum and Dad. Mostly my Dad. I guess really because my Dad's a boy, and I'm a boy, and my Mum's a girl. Just because I'm IN a girl, doesn't mean I'm going to BE a girl. Cause my Mum could inhale ... something like ... skin ... skin cells? (questioning tone) that flake off and that could come into the lungs, go through some sort of way and ...(trails off). DNA looks like a mix of blood and skin, I think ... it might be in the blood, that produces different blood colour ... and that's down to whether the skin's blood is dirty, whether it's got enough oxygen in it. I just picked it up over time from channels like *Discovery, Mythbusters,* maybe. Can use DNA to clone animals ... to clone people ... could use it for future development ... I don't really know HOW we could use it but	

				probably in the future we could use it for something like future development in hospitals, to help other people.	
		B	Adam	DNA – isn't it to do with life systems? That's all I basically know. It's in the stomach and around the heart. I know it's a spiral shape, with little dots (hand gesture). DNA runs through the blood, can take out blood and see who you're related to, I know about that from my family, we had related tests done. It's found in fingerprints too, DNA is in the lines on your fingers.	
		G	Clarenne	DNA is for growth, it's what makes you look like your parents, how you turn out. It's in the blood, like little particles. It makes you develop parts of your body as you get older, parts you don't have when a kid. I've overheard my parents and doctors talking about DNA. No, police don't use DNA. Can test to see if DNA is healthy, it's something to do with disease and with getting old.	
		G	Cherilyn	Can do a DNA test so if your blood matches to your parents, that means you're related, but if they don't, you might have been adopted. DNA can be the same as others in your family but different from everyone else. Everyone's DNA, apart from your family, is different. DNA is in blood, fingerprints, it circulates through your body. Can use DNA to prove whose family you're in if we ever need to know, if we don't know. I read lots of different types of books, whenever I get a chance, I just grab a book and read, Health and Science books. Also, DNA - if you've touched a glass they can look at your fingerprints and say who it was. On *Bones*, they use fingerprints to tell who that person is if they don't know. DNA helps doctors find sickness too.	19 and 20
		G	Gia	I don't know much about DNA and I've not heard of genes. If you don't know who your grandchild is, can do a blood test for DNA.	
	6	G	Aleeza	Genes mean you come from the same family, DNA has to be the same for relationships but not exactly the same. DNA is in the brain and some other parts. DNA is a criss-crossing swirly thing, you can't see it. DNA is used to tell if you've got a disease. It can also tell similarities between people, like between a father and a baby. We use it to find a missing person, to identify them. I think you can use it for crime too. I looked it up in fact books in the library and on the Internet, also on the Jeans for Genes advert, and in an SBS documentary.	

			B	Harlan	When adults have babies, genes go into the air, when they're still in the Mum, kittens get genes. DNA is in blood cells, it's really little, microscopic. DNA is the way they act or behave, genes is in their blood. I learned about DNA from hospital, it's on a birth certificate, also on hospital shows and the *News*. You can use DNA for identification, you can compare a child to their Mum and Dad. You can use it to see if you've got a disease in cells. You can use it to see if you've used drugs.	
			B	Joey	Girl and boy genes are injected into kittens. Everyone has different DNA, no one's the same. I think there's even some difference in identical twins. DNA is in blood, fingerprints and the oil on your skin. We have DNA so that people can tell who did it, the crime. I found out in the Internet, I look up stuff. Also on crime shows, research channels like *Discovery*, and on SBS. Can collect DNA blood in science places to find out who's the father, or about diseases, like in chemistry research.	
			G	Diana	Genes run through the family, I have same eye colour as Dad, my sister has same eyes as Mum. It's for hair colour and skin too. DNA is blood, it's in all of your cells and your brain. It's invisible. It makes you a part of your family. Genes is a part of you, DNA is your uniqueness inside you. DNA is your blood type. You can be identified by your DNA and your fingerprints, no one's is the same as each other. You can use DNA to tell if you've got a disease. And you can take blood from them and the possible father and look for similarities. If there's a robbery, can get fingerprints, that's DNA, and put them in the computer and find out who it is. Or blood would work as well. I learned about DNA in science in my old school when we did Jeans for Genes day.	18
			B	Anton	I only know about DNA. Skin, hair, blood samples and fingerprints contain DNA. It's very little, microscopic. Can use it to solve crime. Can use DNA to find out how healthy you are. Also to see if you're related to other people. They use DNA for forensics. But is there dead DNA? I'm not sure what happens to DNA when they die. DNA keeps us alive. We use DNA to identify ourselves. Can also use DNA to clone dogs, you use the DNA of the one you want to clone. They research it in labs.	6
			G	Hanja	Both genes and DNA make you look like parents. All living things have genes and DNA in the cells, they are little cells. DNA doesn't	

				do much, it triggers what you look like. At crimes, can collect it and see if DNA fits or matches. Can use DNA to see if someone's adopted, if they're related. I saw it on crime and mystery shows and on the *News*.	
		B	Brian	I only know DNA, I don't know genes, but chromosomes sounds familiar. You can take DNA out of one thing and put it into something else to change it. Little bits of DNA make things look like they do. DNA is everywhere, it looks like a twirly ladder, it helps you live. If you don't have any DNA you'd be under a gravestone. But when you're dead you still have some DNA in your bones. We can use DNA to change colours of eyes, hair and skin. And to find people. Can use DNA to identify dead people, like on *Bones,* can compare DNA to photos. Can use DNA to see if someone's adopted. Can also use DNA to find someone who's escaped. I've seen DNA on science shows and crime shows on TV, and then I looked DNA up on the Internet and read it in books.	
		G	Elvie	Genes come from inside, they are microscopic and squiggly. They make you look like you are, short or tall. DNA can compare different people and find out how they're different. In cloning, we use DNA for making another exactly the same. Yes, DNA can be used to solve crime and for identifying a dead person. I learned most about DNA on *Home and Away* and the *News*.	
	7	G	Tallulah	Genes – things from inside adults go into the little kittens. If big cats have babies, the same genes are in the babies as the parents. DNA is round the belly and in the head, like little particles. Both have to do with the body and having babies, the DNA helps to find out what, where stuff is, I can't really explain it. If you've got a parent who doesn't know if it's their kid, you can run a DNA test. Can use it to solve crime if there's fingerprints on stuff. I saw a documentary on cloning too, Doctors use DNA for that.	7
		G	Cherry	In genetics, cells from both parents are mixed into one, but there may be more of Mum or Dad's genes. DNA is your blood in you, there's different groups of DNA. DNA might be your personality, image, what you look like, facial features, height, build, all these things are the genes or DNA. They are really small and circle-shaped. They make you resemble your parents, identify you with your parents. The genes and cells stick together and blend	14

				into one person. Genes are like from your parents but DNA is your blood, it has a bit of your parents in it but it becomes yours. I learned about DNA on Doctor shows like *Grey's Anatomy*, on *Bones*, and other crime shows. And a bit from the *News*. We can donate DNA blood to people. We can use DNA as evidence if someone's been stabbed. We can run tests on suspects. And we can use it to find family too.	
		G	Geordana	DNA is normal blood. I don't know genes. I learned about DNA on *Medical Emergency* and *Criminal Minds*. We can donate blood DNA to someone else. In crimes, can take DNA to see if someone was injected.	
		B	Connal	Genes don't just come from your parents, it can come from other relatives. They are all over the body and inside as well. Genes and DNA are passed down from the parents. Genes are what makes you look the same as others but DNA's on the inside, in your blood. Can use DNA to find out relationships, to identify people. If there's been a crime, can look for fingerprints and get the DNA off it to find out who did it. I learned about DNA from random conversations with my parents, in my old school, and from *Dr Phil, Find My Family* and the *News*.	
		G	Hailey	DNA is in the blood, it controls what you look like. DNA is really small. It makes people who they are. Both genes and DNA connect you to your parents. I learned about DNA on the *News* and on shows like *NCIS*. Also I've seen posters about it in hospitals, and read a bit in science and health books. I think there are cures from diseases from DNA. You can use DNA to find who's been murdered.	
		G	Angela	DNA and genes make you take after your parents like dark skin. DNA is all around your body in your blood, genes are near your liver and guts. I've seen DNA in a cartoon, it looks like a ladder, like a cord. DNA is in your genes cause that's what makes you you, everyone's got blood and genes. We can use the DNA blood groups to identify people. We can use DNA to find lost relatives – genes and DNA are passed on through the family. We can use DNA to see who got murdered. I know because Mum was a nurse and I've seen it on documentaries.	
		B	Saul	When parents have intercourse they pass on their genes. Everyone has different DNA, it tells who you are. It's in fingers, toes, ripples in skin, hair, eyes (they're all different), blood.	4

				Genes are passed on from your parents and are all over your body. DNA is microscopic. We use it to find out who you are. DNA gives information about you, but genes are looks etc that you get from your parents. Like we can do DNA fingerprints to solve crime. We can cross two animals' DNA to make another type of animal – like elephants and mammoths – can take mammoth DNA and put it into elephants. And in China, they're putting human DNA into robots. I don't really pay attention to TV though, it depends on what it is. I also heard about it because my older sister was doing homework about DNA, and in my old school, in Year 4/5, we talked about how we get genes and what they're used for.	
		B	Olin	When adults reproduce, genes and DNA mix. I've heard of chromosomes too. DNA is all over, in hair, eyes, saliva and blood. DNA is like strands, twirly things with dots (spiral hand gesture). DNA is what you have that makes you unique, genes come from Mum, Dad, grandparents, blood relations. DNA is used for cloning. We can donate DNA blood to someone – if it's type A or B. We use DNA samples – fingerprints, hair strand – for crime – no one's are the same. Can find parents by scanning DNA to compare and find them. I learned about this in science magazines – Mum's a teacher – and a bit on the Internet, also science TV shows and it's on the *News* sometimes.	
		G	Amberly	DNA is everywhere, both inside and outside. Can use DNA to see who broke into a house. Doctors use DNA too but I'm not sure what for. Can use DNA to find relations, see if they're the same blood type. I've mostly heard about it in SBS documentaries.	
3 Low SES NSW A very small school No free access to channel 10 (*NCIS*, *Law & Order*)	5	B	Arunta (twin of Alkira)	I know something is passed from parent to baby to make them look the same. I've not heard of genes but I have heard of DNA. DNA has to do with blood types and fingerprints, it helps to identify us. It's found everywhere. It can find out criminals and relatives. I learned about DNA on *Law & Order* and *Cold Case*. Oh, it must be DNA that parents give to offspring to produce similar features!	3
		G	Alkira (twin of Arunta)	I've not heard of genes, I've heard of DNA but I don't know much about it. Mum has talked about DNA with her friend, I think it's in the head, and it's little, you can only see it in a microscope. No, I don't know how it can be used. I've heard it mentioned on science TV shows and on *Animal Planet*.	

	6	B	Ian (younger brother of Kayley)	Humans have DNA and genes I think, DNA is in the blood. We use genes and DNA to tell us apart, to know who's who.	
	7	G	Kayley (older sister of Ian)	DNA is a big long name for a type of acid that makes up the genes. It's what tells your body how to grow. Chromosomes are in each cell, there are 46 in each cell but 23 in a reproductive cell, so when two join, you get 46 again. One of them's a spiral, I think that's chromosomes. Genes are for reproduction and to tell the body how to grow, genes work by producing messages which go to the brain and other organs to tell them how to grow and develop. Genes are made of DNA. I read this in a dictionary for school. DNA can be used to diagnose disease, also to solve crime. We can use DNA to track down the person who was the victim as well as the criminal. Can also use bones for forensics, and can use DNA to tell who the father of a baby is.	17
3 – larger school, same town	5	B	Paul	Yes, I've heard of DNA, genes and chromosomes. Can use DNA to track soldiers who died in Gallipoli to see who they're related to. Can use DNA to make clones. DNA is in hair, blood, fingernails and in skin maybe. DNA is like a twisty ladder. DNA and genes are similar but their shape and the way they work is different. Can use DNA from healthy people for sick people, like blood transfers. It's in your fingerprints to solve crime, track guns or weapons. I like that TV science like crime shows, teaches kids about stuff they'd only learn in college or high school. Then I looked it up in an encyclopaedia.	15
		B	Tim	Genes run in the family, DNA is inside us, the blood. It makes parents and offspring look the same, but genes are given from the adult to the baby. I heard about it in school a couple of years ago, and a bit from Mum and Dad and in a novel I read. I know scientists use DNA in experiments but that's all.	
		G	Coreen	I've not heard of genes or chromosomes, I think I've heard of DNA. A DNA test will show who you're related to.	
	6	G	Jemilia	Dad said DNA gets passed on from the bloodline through the family, DNA is in the blood. I think offspring look like parents because they get things from their Mums through the milk, and bits from sex organs. I don't know any ways DNA can be used.	
		G	Eliza	I know more about genes, I know that they can be passed way through generations. Like if	

				your great great grandparent has cancer, you might get it even if it missed in between. Genes and DNA are both in my brain and heart. I seen on TV that DNA looks like 2 pieces of wire bent, with little balls in between. DNA could be for your health, like healthy levels of blood sugar. I learned about DNA from Doctors, specialists, medical shows and crime shows. Also from magazines, lifestyle ones. A bit from school – about this research and about how bodies are made up. And when Mum talked about growing and changing bodies. Everyone's got similar and different genes in their fingers so we can go by fingerprints in crime. It can be used at the hospital, to find out what type of blood you've got. We use DNA to find out how they died and to find people from their family.	
		G	Cathleen	Babies take samples of DNA from Dad and Mum, but I don't look like my parents, I look like my aunties. Every living thing has DNA, inside your body. DNA is to make us all different, even twins don't have the same fingerprints. DNA is curly things with coloured dots round it (hand gesture in spiral). DNA tells us who we are related to. I learned about DNA from TV, the *News*.	
		B	Jacob	I've sort of heard of DNA, not the others. DNA is in your body. DNA tells who your Mum and Dad is – your family. Can use it to see if you were at a crime scene . . . or not. I learned about DNA from school and TV crime shows.	16
4 Lowest SES SA No free access to channel 10 (*NCIS*, *Law & Order*)	5	G	Sharnie	DNA is to make you look like Mum or Dad. It can tell whose Daddy is whose. Hmmm I think that might be genes, I'm not sure. I heard Nanna talking to my Aunty about being skinny, she said "She's got my genes".	
		G	Tirranna	I've only heard of DNA and I don't know what it means. Humans have DNA, I think it's in the head. I know it makes something, I don't know what. I've seen it on movies we've watched at school. Used for pa . . . ter . . . nity, can use DNA to find out who's the Daddy, and yes, to solve crime.	
		B	Parri	I don't know much about DNA. I know police use it. Only some humans have DNA. I think DNA is dangerous, it kills people. I know on *Bones* they use DNA to find out who the murderer is.	1
		B	Coorain	I don't know about DNA or genes or the other one.	

	6	G	Allirea	I only know about DNA. Last year at school we watched this movie about endangered animals. They found some DNA of the Tasmanian tiger and put it in water and it was growing. Can use DNA to solve crime and to grow DNA of things. It can't be used to test who the father is though.	
		G	Lamilla	I don't know anything about DNA or genes.	
	7	B	Burnu	I got my DNA from Mum and Dad, it's in the blood. It's very small and thin. It comes together with other DNAs. DNA can be used for cloning. It can be used to solve crime, and I think it can also be used to relate people and diagnose disease but I'm not sure.	
		G	Korra	We can look for DNA in hair and fingerprints but it's in all cells. I found out about DNA from TV shows, crime shows, not the *News* or from ads. Yes, it's used to solve crime and to find your family if you've lost your family. Don't know about disease.	8