

GENETICS CURRICULUM MATERIALS FOR THE 21ST CENTURY

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ABSTRACT

Genetics is a fast evolving area of science and current curriculum materials often do not contain accurate and up-to-date information. Most genetics teaching in Australian schools is based on simple Mendelian laws of inheritance and does not consider either genetic conditions with multiple loci or those influenced by environmental factors. The purpose of this project was to provide innovative and cutting edge genetics materials for 14-17 year olds (Year 10-12) in Australian schools, which aimed to engage students and encourage evidence based decision-making. In 2008 an Australian School Innovation in Science, Technology and Mathematics (ASISTM) project called *Genetics Education in the 21st Century* brought together seven biology teachers from secondary schools in Western Australia, together with genetic researchers and science educators from Western Australian universities and genetic researchers from industry, for a series of three days of Professional Development (PD) workshops. These workshops focussed on three genetic conditions which have an increasing prevalence in the Australian population, affect school aged children and have both genetic and environmental factors affecting their development. These conditions were asthma, coeliac disease and diabetes. Accurate, up-to-date and relevant curriculum materials based on each condition were developed, presented to teachers, trialled in classrooms and adjusted according to feedback. The materials were then published as a workbook, together with case studies designed to encourage students to use their understanding of genetics to make and support their decisions. This book was titled *Genetics education in the twenty-first century: a guide for Australian high school teachers*.

Keywords: Genetics Education, Curriculum Materials

BACKGROUND

In a national study on science teaching in Australia, Rennie, Goodrum and Hackling (2001) stated that, "scientific literacy is a high priority for all citizens, helping them to be interested in, and understand the world around them, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions, investigate and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well-being" (p. 455). It is essential that school science provides young people with the understanding and skills to become scientifically literate citizens in society. In order to achieve this, science teachers need to engage students with relevant and accurate information and activities, as well as develop their skills in critical thinking and evidence based decision-making.

In 2008, the federally funded Australian School Innovation in Science and Mathematics Project (ASISTM), supported projects which aimed to bring about real and lasting improvements to the ways in which science, technology and mathematics were taught in schools (Australian School Innovation in Science and Mathematics, 2004). *Genetics Education in the 21st Century* was an 18 month project focused on genetics education in Western Australian secondary schools. The aim of this project was to develop a range of innovative and current curriculum materials for use by secondary school teachers, which engaged students in their study of genetics using relevant genetic conditions, as well as encouraging evidence based decision-making.

In Australian secondary schools, general science is taught as a compulsory subject in Years 8 to 10. In Years 11 and 12 students are able to choose their subjects and science is divided into specific fields of study. Genetics is usually taught in Year 10 science and also as part of Biology and Human Biology in Years 11 and 12. Usually science teachers are required to have a tertiary degree in science, however in remote schools it is not uncommon for teachers to be teaching outside of their field of specialty. Thus, teachers need to be provided with sufficient support and information, so that they feel confident teaching topics, in which they may not be knowledgeable.

The field of genetics is rapidly developing, making it difficult for the curriculum resources used by teachers (e.g., textbooks) to be kept up to date. Most genetics teaching is based on simple Mendelian laws of inheritance and does not consider conditions with multiple loci such as asthma, where no one allele accounts for more than 10%

of an individual's overall susceptibility to asthma. These laws also do not consider the influence of environmental factors on the expression of certain genes. For example in identical twins (where both individuals have the same genome), if one twin has type 1 diabetes the other twin develops diabetes only half the time. Environmental factors must play a part. Concepts such as these can be difficult to understand, so curriculum materials must be easy to understand and engaging.

As the field of genomics progresses, the interaction between the environment and certain genes are becoming more apparent, yet the teaching of genetics continues to focus on single gene disorders such as sickle cell anaemia and cystic fibrosis. The worldwide increase in conditions such as asthma and diabetes are almost certainly caused by an increase in environmental influences. The following three conditions were specifically chosen for our curriculum materials as common examples of multifactorial human conditions. An individual needs to first inherit the genetic predisposition for the condition and then be exposed to an environmental trigger, before they display symptoms of the condition.

Asthma

Asthma is a significant health problem in Australia, with prevalence rates that are high by international standards. It affects over 2 million Australians (out of a population of 22 million): one in seven primary school-aged children, one in eight teenagers and one in nine adults (Health Insite, 2009). Asthma appears to result from genetically susceptible individuals being exposed to particular environmental stimuli. There have been a number of genes discovered that are associated with asthma, with no single allele accounting for more than 10% of an individual's susceptibility to asthma (Le Souef, 2002). The genetically susceptible individual must then be exposed to an environmental factor to develop asthma. There have been many factors identified as possible triggers for asthma, including excessive cleanliness and early exposure to respiratory viruses.

Coeliac Disease

Coeliac disease is an autoimmune disorder, where the ingestion of gluten causes an abnormal immune response to occur in the intestinal wall. Gluten is a protein found in wheat, oats, barley and rye. The incidence of coeliac disease has doubled in the past fifty years so that currently in Australia, approximately 1 in 100 people have the condition (Green, 2009). Individuals are born with a genetic susceptibility to the condition, with two genes strongly associated with coeliac disease having been identified. Environmental factors also play a significant role in the development of the condition. Some factors which may be significant include the protective effect of breast feeding, certain gastrointestinal viruses and the age of dietary introduction of gluten.

Diabetes

The World Health Organisation (2009) recognises that diabetes is currently the fastest growing chronic condition in the world. In Australia, about 3.2 million people are affected with diabetes or pre-diabetes (Australian Institute of Health and Welfare, 2008). The prevalence is increasing so dramatically that it is predicted to double by 2050. It is well accepted that there is a significant genetic component influencing the development of diabetes. Type 1 diabetes is an immune mediated disease usually presenting in children between the ages of 5 and 15. It represents about 13% of those people with diabetes in Australia (Australian Institute of Health and Welfare, 2008). In type 1 diabetes, the person must first inherit a genetic predisposition to the disease. Then some factor in their environment such as a virus, triggers the onset of diabetes. Type 2 diabetes is the most common form, affecting approximately three percent of Australians and representing about 83% of all diabetics (Australian Institute of Health and Welfare, 2008). It generally affects people over the age of 40. However, it is now occurring increasingly in younger people. Once again, there is a strong genetic predisposition for type 2 diabetes, with several genes having been identified. However, genes alone are not enough to cause the onset of diabetes and environmental factors such as obesity and a sedentary lifestyle greatly enhance the chance of people with these genes developing diabetes.

Role of Science Education

All of these conditions have an increasing prevalence in Australia and frequently affect school aged children. They are commonly the subject of media articles and government health initiatives. Students are likely to have been exposed to media reports about these conditions. Another important consideration when choosing these three conditions, was the informative health aspects of teaching about them. It is increasingly important that citizens become their own health advocates and that students are provided with the necessary information to maintain the health and well being of themselves and their family throughout their life.

Diabetes is of worldwide importance with the prevalence expected to double in the next 10 years. Type 2 diabetes is especially dependant on environmental factors. The most important environmental factor is thought to be obesity. If people with a greater risk of type 2 diabetes lead a healthy and active lifestyle, they are less likely to develop diabetes. The environmental factors for the development of asthma are still being researched, however the key to management of the condition is appropriate treatment and a personal commitment to good self-management. This includes being aware of and avoiding triggers for an asthma attack. Coeliac disease requires a person to eat a gluten free diet, which can be socially awkward at times. By educating students about these conditions, their possible environmental triggers and treatments, they can be aware not only of the implications for others living with these conditions, but also of the benefits of a healthy lifestyle for themselves.

Research suggests that students taught how to make decisions using genetics based social issues gain a better understanding of genetics concepts (Venville and Dawson, 2010). There are many socioscientific issues in the field of genetics, such as genetic testing and the growth and use of genetically modified food. Such issues are contentious and provoke opinionated arguments from students on both sides of an issue. However students need to use evidence and facts to support and defend their argument and this is known as evidence based decision-making. In order to promote these skills and enhance students' critical thinking, curriculum materials based on genetic socioscientific issues were developed and trialled in collaboration with teachers. This paper describes the development and trialling of these genetics curriculum materials.

METHOD

This project involved professional development (PD) days, that provided teachers with accurate and cutting edge information which they could use in the classroom. Seven exemplary biology teachers were invited to participate in this project and they were brought together with genetics researchers and science educators from Perth universities, as well as experts in genetic testing from industry. Teachers attended two full day and one half day PD workshops where they were presented with talks about current genetics research, genetic testing, evidence based decision-making and pedagogy.

Each day involved an introductory presentation on diabetes, asthma or coeliac disease and its relevance to Australians, a discussion with the teachers about possible learning activities, and local genetics researchers specialising in each condition speaking about the latest research findings.

Professional Development Day 1 – Introduction to Genetics Teaching

The first day was an introduction to the project and a chance for the teachers to discuss their experiences teaching genetics. Teachers were asked to bring in samples of worksheets and activities they used in the classroom to teach genetics. These examples were discussed and the teachers discussed the type of materials that they needed to teach genetics effectively; accurate, up-to-date, relevant to Australian students, easy to understand and easy to use. They wanted real life case studies of genetic conditions and issues which occurred in Australia. Several talks were given by scientists involved in genetics research and genetic testing. Figure 1 lists the presentations made on the first PD day. On this day no genetic condition was focussed on. However, teachers were informed about evidence based decision-making and introduced to several socioscientific case studies.

Figure 1 Outline of professional development day 1

Presentation
1. Recent trends in genetic epidemiology and population studies
2. Genetic testing for human disorders
3. Keeping Australia safe: Genetic testing and biosecurity
4. Inquiry based learning
5. Evidence-based decision-making
6. Curriculum planning workshop

Professional Development Day 2 - Asthma

The second PD day was based around 'Asthma'. The teachers were given an introductory presentation about asthma, its prevalence in the world and Australia, multifactorial nature, possible environmental risk factors and current genetic research. The curriculum materials based on asthma were presented to the teachers and their initial thoughts discussed. Teachers were also introduced to a three dimensional pedigree available online, which

could be used in the classroom as a tool to teach inheritance, and took part in a workshop on common alternative conceptions held by students about genetics (Venville and Treagust, 1998).

Figure 2 Outline of professional development day 2

Presentation
1. Asthma – a Multifactorial Disorder; Trends and Recent Research
2. Celestial 3D (3D Pedigree for Teaching Modes of Inheritance)
3. Current Research in Genomes
4. Alternative Conceptions in Genetics Education

Professional Development Day 3 – Diabetes

The third PD day was based around 'Diabetes' and teachers interacted with several high-profile researchers involved in current diabetes research. The first presentation was an introduction to diabetes, the prevalence and impact on Australians, the different types of diabetes, the genetics of each diabetes type, possible environmental triggers and current treatment. Teachers were introduced to research into using lupin (a seed), as a weight control measure and also current research on type 1 diabetes. Next a workshop occurred using sensory evaluation of bread types as an example of a possible classroom activity, followed by a discussion on different open-ended investigations relating to diabetes.

Figure 3 Outline of professional development day 3

Presentation
1. Introduction to diabetes
2. Use of lupin-enriched foods to maintain a healthy body weight
3. Research on causes of type 1 diabetes
4. Sensory evaluation of bread texture
5. Open-ended investigations related to diabetes

There was no specific workshop provided about coeliac disease. However, using previous feedback from teachers about the types of materials which they needed, curriculum materials were developed using the same criteria that was used with 'Asthma' and 'Diabetes'. These materials included worksheets based on the sensory evaluation of different bread types.

RESULTS

Curriculum materials were developed on the three genetic conditions; asthma, coeliac disease and diabetes. These were further improved to include illustrations, pictures and newspaper articles and were published as a 32 page booklet entitled *Genetics education in the twenty-first century: a guide for Australian high school teacher* (Dawson, Venville and Carson, 2009). The booklet was divided into four sections, three based on the genetics conditions and one section based on genetic case studies to enhance evidence based decision making skills. The first three sections comprised teacher notes, background references and Website addresses, and student activities.

The first section is 'Asthma'. This section includes teacher notes which give detailed information about the symptoms of asthma and the possible triggers of an asthma attack. Interesting facts are included which teachers can share with students in class discussions. For example under 'Cigarette smoke':

Studies show that a child with asthma has more frequent and more severe asthma attacks if exposed to smoke. In fact children with asthma whose parents smoke at home, are twice as likely to have asthma symptoms all year long as children of non-smokers. It is estimated that children of parents who smoke are exposed to the same amount of nicotine as if they were actively smoking 60 to 150 cigarettes a year (Dawson et al, 2009).

The first student worksheets are based on what the symptoms, triggers and treatment of an asthma attack are. Students are also given the opportunity to compare the rate of asthma in their class with that in Australia. The next worksheet is based on an article from the local newspaper, which states that, 'Babies born by caesarean section are up to 50% more likely to develop asthma, according to a study of 1.7 million births' (Guest, 2008). This is followed by a scenario about a fictional family, where the parents are using this information to decide on a natural birth versus a caesarean. Students are asked their initial opinion and then given five questions to guide them through the evidence needed to support their decision.

'Coeliac Disease' is the next section of the booklet. The teacher notes provide information on coeliac disease in Australia, its epidemiology, symptoms, diagnosis and treatment. Once again, interesting facts are included to share with students. For example:

Little data is available on the occurrence of coeliac disease in animals. In companion animals (pets), many veterinarians believe that the withdrawal of gluten from dogs' diets can 'cure' many conditions including skin allergies and epilepsy. These vets consider gluten an abnormal addition to dogs' diets, as their gastrointestinal system has adapted over thousands of years to the diet of a carnivore (Dawson et al, 2009).

The student worksheets begin with an article from the local newspaper about a seven-year-old boy who had been ill until he was diagnosed and treated for coeliac disease. Students are then asked several questions about the article, to highlight the diagnosis, symptoms and treatment of coeliac disease. A practical activity is also included, where students evaluate four different types of bread including gluten free bread, based on the characteristics of appearance, texture and taste. Students are also asked to score each of the bread samples based on its 'healthiness'. Teachers are provided with answers to all student worksheet questions.

The next section of the booklet is 'diabetes'. Teachers are again provided with notes on the condition, which include the different types of diabetes, symptoms, diagnosis, treatment, complications, and diabetes in indigenous Australians. Again interesting facts are included. For example under 'Diabetes in Indigenous Australians':

Some scientists believe in the so called 'thrifty gene'. The idea behind this is that indigenous people were hunters/gatherers and food was not always abundant. It is believed that evolutionary selection pressures have led to a gene which is efficient at using scarce nutrients. So what is a survival advantage in times of scarce food, becomes a liability in the modern world with excess food and this leads to obesity and diabetes (Dawson et al, 2009).

The worksheet provides a fictional story about a young girl showing symptoms of diabetes and students are given a table to complete which compares type 1 diabetes with type 2 diabetes. Students research these two types of diabetes using either the library or the internet. Website addresses are provided. Questions are then asked about the original story as well as prediabetes and the increasing rate of diabetes in Australia.

The last section in the booklet was included for students to practice and improve their evidence based decision-making skills. It is called simply 'case studies'. Six different scenarios are included and all are based on genetic socioscientific issues. They include scenarios on genetically modified food, genetic testing, genetic population epidemiology, genetically modifying animals and forensic testing. In each case study, students are presented with a possible scenario. For example:

Recently the Flavr Savr tomato went on sale in the USA for the first time. Normal tomatoes rot quickly once ripe. To overcome this, producers pick them when they are green and allow them to ripen during shipping and storage. Many people complain this makes the tomato tasteless. The Flavr Savr tomato has been genetically altered to prevent it from rotting as quickly as normal tomatoes. It can be picked once ripe and will not rot during transport or storage. Producers claim that this makes the Flavr Savr tomato taste better (Dawson et al, 2009).

Students are then asked for their initial opinion on whether the Flavr Savr tomato should be grown and sold in Australia. They are then guided through the development of their argument by being asked, what further information would help in making their decision, what are the advantages and disadvantages of their decision, how would they convince someone else their answer is the best one and, lastly, if they have changed their opinion. These scenarios have been specifically designed to present a dilemma, so there is no clear right or wrong answer and class discussions should be encouraged.

Initially 250 booklets were published as a classroom resource. They were spiral bound and the pages printed in glossy colour, so that teachers could easily photocopy student worksheets. These were distributed firstly to the teachers who took part in the professional development days, then to teachers attending the local State and National Science Teachers' conferences. A PowerPoint on each of the diseases was presented and the booklet was then distributed to participants. This booklet was also distributed to members of the Science Teachers' Association of Western Australia (STAWA).

CONCLUSION

Almost all of the 250 copies of *Genetics education in the twenty-first century: a guide for Australian high school teachers* have been disseminated throughout Australia and there has been an overwhelming positive response to the materials. The seven biology teachers who attended the PD days all agreed that their initial list of needs for curriculum materials had been met. They were; accurate, up-to-date, relevant to Australian students, easy to understand and easy to use. The booklet graphics were of a high quality and teachers appreciated the colourful images and layout.

It is hoped that further copies of the booklet will be published and distributed to Australian secondary school teachers for use in the classroom. We are hoping to also use these curriculum materials in classrooms to improve students' understanding and awareness of these conditions, in particular asthma and diabetes and also to improve students' reasoning and evidence based decision-making skills. In this way we aim to empower students and provide them with some of the skills needed to become a scientifically literate citizen in society.

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