Genetic Technologies, DNA & Disease

Secondary sourced inquiry task for senior biology

Summary

Medical applications of genetic technology are increasingly important in twenty-first century healthcare. DNA sequencing is becoming an affordable tool for doctors, and gene-based therapies continue to emerge. This investigation gives students a deep understanding of a genetic disease and the use of genetic testing or another genetic technology to diagnose or treat it. Students evaluate secondary sources to consider the social, economic and cultural contexts of these technologies and construct scientific and ethics-based arguments regarding risks and benefits.

Activities and syllabus links

Students…

- Research a genetic disease
  - Research Matrix activity
- Explore medical applications of genetic technology
  - Six W's activity
- Practice ethical and evidence-based justifications
  - Genetic Testing Issue Scan
- Evaluate the benefits and risks of a genetic test/technology for a chosen genetic disease
  - Evidence Plan Template
  - Peer review
- Communicate findings of evaluation
  - Report/presentation
  - Assessment

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- Conceptualisation of gene→protein→phenotype→ population (ACSBL078-84)
- DNA sequencing/profiling (ACSBL086)
- Using scientific knowledge to evaluate risk (ACSBL071)
- Influence of social, economic and cultural contexts (ACSBL070)
- Use of scientific knowledge to evaluate projected social impacts (ACSBL074)
- Construct questions for investigation (ACSBL061)
- Interpret a range of texts, evaluate claims and conclusions, use reasoning to construct scientific arguments (ACSBL065)
- Communicate to specific audiences and for specific purposes (ACSBL067)

Teacher background notes

In the 15 years since the human genome project, the cost of DNA sequencing has decreased to the point where the genome of an individual – their entire set of genetic information – can be made available for use in healthcare. This has immediate impact on the way that rare genetic diseases and cancer are diagnosed and treated. It also suggests a future where genetic information can be used to make everyday health decisions. Advances in genetic engineering mean that genetic therapies will also be increasingly common. Tomorrow's citizens will not only need to understand DNA and the uses of genomic data, but they also need to have the skills to find and critically analyse information, and make well-informed and reasonable decisions about their own health and the implications for society.

This inquiry task addresses elements from all three strands of The Australian Curriculum, Biology, Unit 3:Heredity and continuity of life- i.e. Science Inquiry Skills, Science as a Human Endeavour, and Science Understanding. Genetic disease and medical genetics is used as a context for developing understanding of how genes and variants effect phenotypes, the application of genetic technologies, and the related social, economic, cultural and ethical considerations. The task also develops numerous "21st century skills" including critical thinking, ethical understanding, ICT capability, literacy, and an appreciation of difference and diversity.

This task involves two phases. The first phase involves in-class activities that build the necessary background knowledge for the task. The second phase involves student research into the risks and benefits of a chosen application of genetic testing. including both the clinical benefits and limitations as well as social, ethical and legal considerations. The task can also be adapted to include other genetic technologies such as gene therapy and embryo editing

Although the research undertaken in this task secondary-sourced, it is not simply an informational report. The task is based on real-world frameworks for evaluating genetic tests. For example, before a new genetic test is approved in Australia, the Medical Services Advisory Committee creates a "Clinical Utility Card", which reports on the benefits and limitations of the test as well as social, ethical and economic considerations surrounding its use. You can read more about such approaches in:

> How is genetic testing evaluated? A systematic review of the literature
> https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5945588/
> Pitini, E., De Vito, C., Marzuillo, C., D'Andrea, E., Rosso, A., Federici, A., … Villari, P. (2018). *European Journal of Human Genetics*, *26*(5), 605–615. http://doi.org/10.1038/s41431-018-0095-5

The task can also be modified to include evaluation of other genetic technologies including gene therapy and embryo editing using CRISPR.

About Us

The Kinghorn Centre for Clinical Genomics (KCCG) is a research centre within the Garvan Institute of Medical Research, located in Darlinghurst, NSW. The focus of KCCG is realising the clinical value of the genome for precision healthcare. We have world-class researchers, clinicians and bioinformaticians studying a wide range of diseases and applications of genomic information. The Education and Communication team delivers targeted education and community engagement about genomics for healthcare professionals, teachers and communities. We're committed to supporting teachers with resources and strategies for teaching genetics. If you have not already joined our mailing list, visit our website and subscribe for updates on resources and professional development opportunities https://www.garvan.org.au/kccg-teachers.

In-class activities

Before undertaking the inquiry, students first need to

- Choose and understand a genetic disease to focus on
- Appreciate the various applications of genetic testing and choose an approach to evaluate
- Explore potential social and ethical implications of genetic testing and practice applying ethical principles and using evidence to support claims

The following activities have been designed to meet these outcomes, but can be modified or replaced to suit the needs of the relevant state syllabus or the specific class. The table below outlines the activities. They can be accessed by clicking the links below or via our website www.garvan.org.au/kccg-teachers.
Full teacher guides for these activities are available by emailing kccgeducation@garvan.org.au.

Stimulus materials	Videos and articles that can be used to engage students with the context of medical genetics.
Activity: Research Matrix for Genetic Diseases	-"Systems thinking" matrix for concept-mapping inherited disease -Case studies provide scaffolded practice -Students use matrix to research a chosen genetic disease -Skills in synthesis and referencing of multiple sources -Includes resource guide on a selection of genetic diseases
Activity: Six Ws of Genetic Testing	-Covers the "what/who/how/when/why/whether" of genetic testing. -Problem solving and critical thinking based on case studies of real life applications -Optional: Role play activity for considering implications of genetic tests
Activity: Genetic Testing - Issue Scan	-Ethics activity (introduces bioethical principles) -Students consider a range of perspectives regarding possible ethical, legal and social implications of genetic and genomic testing -Develop skills in evidence-based argument.

An activity such as our Medical Applications of Genetic Technology could be used in addition to or instead of Six W's if other applications of genetic technologies are to be included in the task.

Note on disease selection

During the Research Matrix activity, students select a genetic disease that will form the context for their inquiry. A small selection of diseases is provided in the associated Genetic Diseases Resource Guide, however almost any genetic disease could be suitable, provided:

- The disease has a well-established genetic component (ie at least one causative gene has been found). Multifactorial diseases could be studied if there is a risk variant with a well-defined mechanism.
- The student has capacity to find resources and possibly adapt assignment guidelines as appropriate
- The disease is not covered extensively elsewhere in the course. We suggest avoiding "well known" diseases such as cystic fibrosis and PKU.

About the inquiry

For the inquiry task, students research the risks and benefits of an application of genetic technology for their chosen genetic disease. Students should cover at least two benefits and two risks, and should include at least one social or ethical consideration. The evidence plan template (appendix 1) can be used to summarise their evidence and evaluate their sources. The plan can also be used to practice formatting of references. This template could also be peer reviewed, focusing on the claims, evidence and quality of sources. A suggested rubric is included that uses the "what worked well/event better if" (WWW/EBI) framework for peer assessment.

Inquiry questions

Students should propose their own inquiry question by combining their chosen disease with an application of genetic technology that they learned about in the activities.

Examples of inquiry questions

- Should all newborns be DNA tested for inherited heart disease?
- Should the government pay for DNA sequencing when there is a family history of heritable cancer?
- Should carrier screening for spinal muscular atrophy be a requirement for all parents-to-be?
- Should consumers find out their risk for inherited high cholesterol using online genetic testing?
- (Should genome editing be used to treat inherited hearing loss?)

Questions to prompt students to develop an inquiry question?

- When researching your chosen disease, what challenges or controversies did you come across when it comes to diagnosis, prevention or treatment?
- Can you use the "Six Ws" to propose an approach to genetic testing?
- What ethical or social issues are important for these applications?

Asking students to begin their question with the word "should" will help them to phrase an inquiry suitable for a risk benefit evaluation. We recommend advising students to consider current or 'near-future' applications so they can evaluate in the context of contemporary society.

Resource guide

A collection of suggested resources has been compiled as a starting point for student research. It includes websites, articles, and scientific papers relating to genetic testing, genetic technologies and social/ethical issues. A 'padlet' with these links can be found here http://bit.ly/kccg-padlet

Assessment

The arguments formed using the evidence plan should then be communicated to develop student's science communication skills and to assess the outcomes covered by the task. Appendix 2 lists possible subheadings for a report, but an in-class task, oral presentation or multimedia response could also be suitable. Appendix 3 includes an example of a marking rubric, but this would need to be modified to the specific outcomes in each state syllabus.

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Appendix 1: Evidence Plan Template

A student version of this template can be found on our website

Begin by brainstorming the risks and benefits associated with your inquiry question. Consider the potential outcomes for the patient, their families and the wider society. Include ethical, legal, social and economic considerations.

You cannot cover all of the benefits and risks in your report so choose two or three that are most important or interesting to you. You can copy and paste the table to expand the template to include more claims. Find at least one reliable reference to support each point. This plan will be peer assessed and then go on to form the basis of your report.

For each main point you will include in your report, you should complete the following:

Benefit/risk: Briefly describe the claim you are making. What is the benefit or risk?
Evidence: Why is this a benefit/risk? How significant or likely is it? What evidence from your reference supports your claim? How would you convince someone who disagrees with you?
Reference: Author, year of publication, title of article or chapter, title of publication (eg website, newspaper, journal), url
Evaluation of reference: Consider the author, publication, funding sources and audience. How reliable/valid/appropriate is the reference for your report? Is it peer-reviewed? What biases might be involved?

Benefits
How effective is the test or technology? How useful? How is it better than current approaches to diagnosis/prevention of the disease?
What are the potential positive outcomes: For the individual? For society? What are the cost savings? How is the test or technology ethical?

Benefit 1:
Evidence
Reference
Evaluation

Benefit 2:
Evidence
Reference
Evaluation

Risks
What are the limitations of the test or technology? What are the potential harms: For the individual? For society? What are the costs? Could its application be considered unethical? Can these risks be reduced?

Risk 1:
Evidence
Reference
Evaluation

Risk 2:
Evidence
Reference
Evaluation

Peer evaluation of evidence plan

Outcome	What worked well?	Even better if…
The risks, benefits and implications chosen are clear and make sense for the inquiry question		
The evidence logically supports the claims		
Counterpoints have been considered		
The references are valid and reliable		
Limitations to the references have been identified in the evaluation		

Appendix 2- Report format

The exact format for the report should be modified from school-to-school and year-to-year. The requirements will depend on the needs of the state syllabus and the student group. We have based our suggestions around using a written report, however this could be adapted for other formats.

Basic report format
Introduction with inquiry question
About the genetic disease
About the genetic test or technology
Risks and benefits (evaluation of the inquiry question)
Conclusion

Options for expanding on simple format
(NB: not all of these aspects could be covered in a single report):

Introduction
- Identifies the genetic disease and the genetic technology being investigated
- Outlines the inquiry question and justifies its importance

About the genetic disease
- Symptoms, age of onset, etc
- Range of genes/mutations involved
- What is known about the protein product of the gene(s) involved?
- How genotype contributes to disease phenotype (i.e. how do changes to the protein result in the symptoms)
- Inheritance pattern
- Current methods of diagnosis and treatment
- Prevalence (of disease and/or allele frequency)

About the genetic test or technology
- Scientific methods used
- How it could be (or currently is) applied in the context of the chosen disease

Risk/benefit analysis of inquiry question (should form main section of report)
- Risks and benefits of chosen application of DNA testing or genetic technology in the context of chosen disease
  - This could include
    - Uses, advantages and limitations
    - Comparison with current methods of diagnosis/treatment
    - Social, economic and/or and ethical implications
    - Data on clinical validity and utility (advanced students, refer to NWABR Genetic Testing lesson plan in other teaching resources section)

Conclusions and future implications
- Meaningful answer to the inquiry question based on evaluation
- What might the future hold for the prevention or treatment of this disease?
- What other genetic technologies might be used (either now or in the future) based on this information.

Appendix 3: Sample marking criteria

These examples can be used as the basis for a rubric tailored to the requirements of individual state syllabi and school requirements

Report Components and Marks available	Marks available
Introduction and research question	
Introduction clearly identifies the inquiry question, outlining a genetic disease and a medical application of genetic testing (or other genetic technology) and the importance of the question. The inquiry question is well suited to investigation that evaluates benefit and risk (ACSBL061)	10
About the genetic disease	
Accurately and concisely describes the disease and its symptoms, as well as current approaches to diagnosis, treatment/management and prevention. Clearly explains the link between a genetic variant, changes to a protein, and how these cause the disease phenotype, using well synthesised concepts and evidence of systems thinking (ACSBL081, 082)	10
About the genetic technology	
There is a well-developed description of the way in which the chosen medical application of genetic technology could be employed to detect, treat or prevent the chosen disease (DNA sequencing/profiling or other genetic technology) (ACSBL071, 086) There is a concise and clear explanation of how the technique works, covering aspects that are relevant for the analysis to follow (ACSBL086)	10
Evaluation of genomic test	
Strong evaluation with thoughtful considerations of the clinical benefits/limitations of the approach AND socio-scientific issues relevant to the approach (legal/ethical/economic etc) (ACSBL070, 074) Selection of a wide range of reliable sources and extraction of valid and reliable information and/or data.(ACSBL065) Arguments are well constructed, logical, and supported by evidence (ACSBL065)	40
Conclusion and future implications	
There is an insightful conclusion that provides a meaningful answer to the inquiry question, distilling key information from prior sections. Conclusion provides overall evaluation of the impacts of the chosen testing approach (ACSBL074)	10
Communication (across whole report) (ACSBL067)	
Language is clear, concise and appropriate for an “educated but non-expert” audience (avoids jargon) Paragraphs develop arguments and incorporate evidence in a logical manner Spelling, grammar, and formatting of report allows for easy reading References are complete and follow prescribed format	20
Total (out of 100)	

Appendix 4: Other teaching resources

The following freely available resources may also be useful to support this inquiry

Genetics Home Reference- from National Library of Medicine
https://ghr.nlm.nih.gov/
This is a database from the National Library of Medicine that contains easy-to-read descriptions of genetic diseases and genes. The "help me understand genetics" section contains a wealth of information on genetic disease and technologies

Genetic and genomic testing – Fact sheet from Centre for Genetics Education
http://www.genetics.edu.au/publications-and-resources/facts-sheets/fact-sheet-15-genetic-and-genomic-testing
This fact sheet on genetic and genomic testing contains a lot of the background information needed for the depth study. Authentic resource used for patients.

Personal Genetics Education Project (pgEd) from Harvard University
http://pged.org/lesson-plans/
Lesson plans including: genetics and reproduction, consumer genetics, genome editing and CRISPR, personalised medicine, and scientific themes in personal genetics. The "Introduction to personal genetics" activity includes a good overview PowerPoint presentation. Other lessons could be used for greater depth on a particular topic and to introduce some of the ethical considerations

Introducing genomics- from Nowgen Schools Genomic Programme
http://www.genomicsforschools.org/resource/pos/
This advanced resource provides additional ideas for extending students

'What do you think' from Unlocking Life's Code (Smithsonian and NHGRI)
https://unlockinglifescode.org/wdyt/
Recommended introduction- a brief, interactive website where students answer questions about genomic information and compare their answers to others.

'Bioethics 101' from Northwest Association for Biomedical Research
https://www.nwabr.org/teacher-center/bioethics-101
The Issue Scan activity on our website includes material adapted from NWABR. The full series of six lesson plans includes many other activities that could be useful.

Genetic Testing – Lesson Plan from Northwest Association for Biomedical Research
https://www.nwabr.org/sites/default/files/Genetic_Testing_Lesson6_NWABR.pdf
This advanced lesson plan can be used to expand on evaluating genetic tests. It introduces the concept of clinical validity and treatment availability. It includes prompts for critical evaluation of texts, which may be useful to extend students.

'Highschool Bioethics Project: Genetic Testing' from NYU School of Medicine
https://med.nyu.edu/highschoolbioethics/modules/genetic-testing
This advanced lesson plan includes a number of relevant ethical considerations as well as some research paper extracts to help students consider the impact of genetic testing

Improving your scientific writing style- from Monash University
http://www.eng.monash.edu.au/current-students/download/improving-scientific-writing-style.pdf
A useful set of tips for students on writing in the field of science