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ORIGINAL ARTICLE

Supporting teachers to use genomics as a context in the classroom: an evaluation of learning resources for high school biology

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Abstract
As genomics becomes embedded into healthcare, public genomic health literacy is critical to support decision-making for personal and family health decisions and enable citizens to engage with related social issues. School science education has the potential to establish the foundations of genetic and genomic literacy. The concept of literacy extends beyond conceptual understanding of biological principles to familiarity with the applications and implications of genetics, critical thinking skills, and socioscientific reasoning. We developed and evaluated a suite of resources for teaching genetics and genomics in the Australian senior biology syllabus for students aged 16–18 years. The aim was to increase teachers' knowledge and confidence to teach genetic and genomic content, and their capacity to develop robust genetic literacy in their students. Resources, including an inquiry-based task and five associated lesson plans, were developed and made freely available to teachers online. Evaluation was undertaken between December 2019 and March 2020 with a post-use survey emailed to teachers who had accessed the resources. The 56 teachers who responded rated the resources as high quality, engaging, and well-aligned with the syllabus. Teachers who used the resources self-reported increases in their knowledge and confidence in teaching. They also perceived positive outcomes in their students, reporting that the resources deepened their students understanding of genetic concepts, helped them to consider social and ethical issues, and developed their higher order thinking skills. Findings may inform future interactions with high schools to improve genetic literacy.

Keywords Genetic literacy · Biology education · Genomics education · Socioscientific issues education · Inquiry-based learning · Education evaluation

Introduction

Community awareness and understanding of genetics and its applications are important for the implementation of genomics into healthcare (Green and Guyer 2011; Ricciardi and Boccia 2017).

There have been significant international research efforts exploring the best ways to incorporate the emerging science of genomics into genetics education (Airey et al. 2019). In light of the varying definitions in the literature (Haury and Nehm 2012; Airey et al. 2019), we will consider genetics as an overarching term, genomics as the study of an organism's complete set of genetic information, and genomic applications as the real-world use of genetic information generated through genomic technologies. Familiarity with genetics and genomics can facilitate personal informed consent in research and genomic data sharing (Middleton et al. 2020) as well as participation in civic discussions around applications of genomics in health and other settings (Hilton et al. 2011; Yacoubian 2018). However, studies consistently show low awareness and understanding of genetic concepts among the general population (Chapman et al. 2019; Haga et al. 2013; Ong et al. 2018).

Genetic literacy

Genetic literacy can be defined as "sufficient knowledge and appreciation of genomics principles to allow informed decision making for personal well-being and effective

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participation in social decisions on genetic issues" (Syurina et al. 2011). High school science has been identified as an opportunity to inform health and scientific literacy and specifically, genetic literacy (Boerwinkel and Waarlo 2011; Stern and Kampourakis 2017; Whitley et al. 2020). Boerwinkel et al. (2017) proposed three types of knowledge required for genetic literacy in non-scientists: key conceptual knowledge; sociocultural knowledge about contemporary applications and implications of genetics; and epistemic knowledge such as higher order thinking skills and critical literacy. These components align with earlier frameworks of socioscientific issues (SSI)-based science education (Sadler et al. 2007; Zeidler 2015), in which learning is centred around contemporary, complex, and controversial issues that require both scientific and moral reasoning.

Evidence-based educational approaches

Although conflicting definitions of scientific literacy and conflicting educational philosophies exist globally (Zeidler 2014; Zeidler et al. 2019), the Australian high school curriculum (for students 12–18 years of age) supports inclusion of SSI in science teaching along with student inquiry (Goodrum and Rennie 2007; National Curriculum Board 2008). The science syllabuses in Australia are underpinned by a set of general capabilities, each with a detailed continuum of learning (Australian Curriculum and Assessment & Reporting Authority 2021). One of these is "critical and creative thinking", which includes the higher order thinking skills such as inquiry, problem solving, reflecting, and evaluating. Authentic student inquiry in real-world contexts has been well established as an effective method and practice of teaching for science and related issues (Goodrum and Rennie 2007; Nam and Chen 2017; Rönnebeck et al. 2016; Sadler et al. 2007), particularly in genetics (Brush et al. 2016; Wells 2017). Effective inquiry-based learning is supported by elements of student choice (Dorfman et al. 2017) and scaffolding, which refers to activities and supports that intentionally develop required skills (Belland et al. 2015; Brush and Saye 2002).

Neither SSI-based nor inquiry-based approaches to science education are new, although there remain barriers to widespread implementation (Aivelo and Uitto 2019, Fitzgerald et al 2019). High school teachers have traditionally found genetics and genomics difficult to learn and teach (Kidman 2010; Steele and Aubusson 2004), and report a lack of support and resources (Goodrum and Rennie 2007). The need for teacher professional development (TPD) and teacher-focused resources has been emphasised to support teaching genetics (Larue et al. 2018; Stern and Kampourakis 2017). Links between school science teaching and scientific research institutes have been encouraged as means to engage students in science and to increase teacher confidence and capacity (Goodrum and Rennie 2007; Tytler et al. 2015).

Additional evidence-based educational approaches to support genetic literacy include developing students' argumentation skills (Dawson and Venville 2013) and their ability to apply "system thinking" to reconcile the molecular and heredity conceptualisations of genetics (Duncan and Reiser 2007; Haskel-Ittah and Yarden 2018).

Context and resource development

In this paper, we describe the development and evaluation of a suite of contemporary genetics and genomics-focused resources to support high school science teachers. The aim was to increase teachers' knowledge and confidence, and their capacity to develop robust genetic literacy and critical thinking skills in senior biology students, aged 16–18 years. It was essential to align the resources with local curricula and incorporate evidence-based approaches to genetics education. We aimed to support an inquiry-based approach, aligning with trends in teaching methods and practice as well as a newly introduced requirement of the state-wide biology syllabus for 15-hour depth studies. Depth studies are student-led projects that expand on an area of the curriculum and are tied to mandatory assessment of skills in scientific inquiry (NSW Education Standards Authority 2017; Eaton et al. 2019).

In 2018, a new senior biology syllabus was introduced into the Australian state of New South Wales (NSW). In May 2018, we distributed a needs assessment survey to local science teachers, which included questions on self-rated confidence to teach genetics content, perceived needs for content updates and resources, and preferences for style of teaching support. The survey was emailed to a convenience sample of eight known teachers and posted to existing local science teachers' Facebook groups with thousands of members. Fifty-three science teachers responded, who taught in different locations (metropolitan, regional, rural) and school settings (public, religious, independent). However, these respondents may represent teachers who were particularly motivated or interested in genetics teaching. Teacher responses identified strong interest in resources designed specifically for senior biology including depth studies and lesson plans. Needs related to newer syllabus content, such as gene/environment interactions and population genetics, with more than half of the teachers indicating a need for resources and content updates in DNA sequencing and medical applications of genetic technologies.

Based on this identified set of needs and an audit of the resources teachers reported using, a complementary suite of resources was developed by a clinical genomics education team within an Australian medical research institute

(MRI), in consultation with practising biology teachers. A program logic model was applied (based on Nisselle et al. 2019) to prioritise, develop, and evaluate the resources. Full details of the resource development are reported separately and the resources are available at http://www.garvan.org.au/kccg-teachers.

The lesson plans could be used as stand-alone curriculum-aligned activities, or in support of an extended student inquiry task (depth study) titled "Genetic Technologies, DNA & Disease" (see Table 1). The depth study allowed students to choose study topic areas within a guiding structure that encouraged consideration of SSI and critical thinking. The authentic context for the task was based on the ACCE model (analytic validity, clinical validity, clinical utility, and associated ethical, legal, and social implications) for evaluating genetic tests (Pitini et al. 2018). This approach was simplified for a student audience as an evaluation of risks and benefits.

The resources were made freely available via a website (www.garvan.org.au/kccg-teachers), with suggested answers for activities accessed via Dropbox™ on request by teachers. The resources were presented in workshops for 152 teachers at TPD conferences in 2018–2019, both off- and on-site at the MRI. They were also shared in a Facebook group for biology teachers within the state (NSW). Google analytics indicated that the resource pages received 8,598 visits in the period, and 278 teachers requested Dropbox access in this time.

Evaluation method

Ethics

The collection of evaluation data was for quality improvement purposes and does not reflect human research for the purposes of human research ethics committee review (National Health and Medical Research Council 2014).

Evaluation design

A survey was developed to assess the intended outcomes of the resources as identified in the program logic framework. These included increased teacher knowledge, confidence, and skills, and positive outcomes for students. The survey (see Online Resource 1) contained six sections: participant characteristics; resource usage and modification; resource utility and quality (Likert scales); student learning outcomes (Likert scales); overall teacher outcomes (Likert scales); and open questions. The survey was piloted with four teachers who sense- and error-checked the content.

Data was collected using a post-only survey design in two parts: a short primary survey covering all resources for teachers who had interacted with the resources, and a more in-depth survey focussing on the depth study for teachers who had expressed written or verbal interest in providing feedback on this resource. Teachers who requested access to the resources during 2018–2019 were invited by email to complete an online survey in December 2019, regardless of whether they had used the activities. The primary

Table 1 Description of resources

Resource	Description
Depth study *Genetic Technologies, DNA and Disease*	An inquiry task in which students research a chosen genetic condition and evaluate the risks and benefits of using a named genetic technology to detect, manage, or treat the condition. The evaluation must include legal, ethical, or social considerations. Teachers are provided with an outline for fulfilling the 15-h requirement of a depth study (incorporating the lesson plans below); supporting materials and stimulus resources including links to patient stories; a resource guide for students; a template for students to create a structured evidence plan for peer review; and a suggested marking rubric
Lesson plans	
Tiny Genome	A paper-based investigation in which students analyse the genome of a hypothetical creature to identify variants and map them to phenotypes
Six Ws of Genetic Testing	Scenario-based activities and role-plays encouraging problem solving and critical analysis of the what/who/how/when/why/whether of genetic tests, from diagnosis to prevention
Research Matrix for Genetic Diseases	A concept mapping template for researching a genetic disease using an integrated "systems thinking" matrix (Verhoeff et al. 2008), and example case studies
Genetic Testing—Issue Scan	Ethics activities introducing bioethical principles and applying them to a range of perspectives on the implications of genetic and genomic testing
Medical Applications of Genetic Technologies	A literacy/comprehension activity where students process information from an article to answer the inquiry question: *"Could DNA manipulation for medicine change the human population forever?"*

survey (see Online Resource 1) was sent to 241 teachers, and 56 responses were received. Of the 37 teachers who had indicated interest in providing feedback on the depth study, nine teachers responded. These responses were not included in the quantitative analysis, but responses to open questions (see Online Resource 2) were used to supplement the evaluation.

Data analysis

Quantitative data from the primary survey was analysed by weighting responses from 1 (strongly disagree) to 5 (strongly agree) for the purpose of statistical comparison using IBM SPSS Statistics software. Descriptive statistics were used to provide a snapshot of the sample and describe the distribution of answers to survey items. Correlation analysis was conducted to assess relationships between variables. Group differences were assessed using chi square analysis (categorical data) or independent samples t test (weighted scores were treated as continuous variables for ease of analysis) and p was set at 0.05. Open answer questions from the primary survey were coded using content analysis by two researchers (AP, LM) and are described along with illustrative quotes. Identifiers for the quotes indicate whether the teacher used the depth study (DS) or only lesson plans (LP). Quotes from the nine teachers who responded to the detailed survey about the depth study (DS30-38) are included where they add further insight.

Evaluation results

Survey respondent characteristics

Fifty-six teachers responded to the primary survey (response rate 23%). Table 2 summarises their demographic data. All three school sectors in the state—public (45%), independent (38%), and Catholic (18%)—were represented in responses. The majority were from the capital city and metropolitan areas (66%) with 20% from regional and 9% from rural schools. These profiles aligned with averages for the state, other than an overrepresentation of independent schools, which employ 22% of teachers (Australian Bureau of Statistics 2019). Teachers taught an average of 19 senior biology students, and about half of the teachers had sole responsibility for planning assessment tasks, with the others having shared responsibility. Forty-five percent of respondents had attended a TPD workshop related to the resources.

Table 2 Description of respondents' characteristics ($N = 56$)

School sector, *N* (%)	
Public	25 (45%)
Catholic	10 (18%)
Independent	21 (38%)
Location of school, *N* (%)	
Capital city	27 (48%)
Metropolitan	10 (18%)
Regional	11 (20%)
Rural	5 (9%)
Interstate	3 (6%)
Number of biology students 2019, *M* (SD)	19 (10)
Responsible for assessment planning, *N* (%)	30 (54%)
Attended related professional development workshop, *N* (%)	25 (45%)

Teacher engagement with resources

The majority of teachers (82%) had used at least one of the resources in their biology classes, and most had read the resources that were not used (Fig. 1). Teachers who used resources as part of the depth study (60%) used an average of 3.3 of the 5 lesson plans, compared to 1.9 for those who used only lesson plans. Each lesson plan was used by about half of the respondents, except for the ethics-focused activity "Genetic Testing Issue Scan" which was used by only 35%. Many teachers modified the resources for use in their classroom. Of teachers who used each resource, the proportion who modified ranged from 15% for Tiny Genome to 65% for the depth study. The Tiny Genome and Research Matrix lesson plans were specifically mentioned by multiple teachers in an open question about the "most successful aspect" of the resources.

Evaluation of resource quality

Overall, teachers rated the resources highly. Most teachers (94%) agreed or strongly agreed that the resources were high quality, aligned with the syllabus, and adaptable (see Online Resource 3). Eighty-five percent agreed that the resources were easy to access and use, and 78% agreed that the materials were appropriately pitched for their students. The quality of the resources was reflected in teachers' comments about the "most successful aspect" of the resources including the currency and relevance of the resources, their professional presentation, and the way the resources were structured and aligned to the syllabus. For example:

> "The way it was specifically written to meet syllabus requirements". (DS12)
> "All the supporting activities to consolidate and scaffold for understanding". (DS38)

The lower scores relating to ease of use and being appropriately pitched for students were supported by comments regarding the most challenging aspect, which frequently

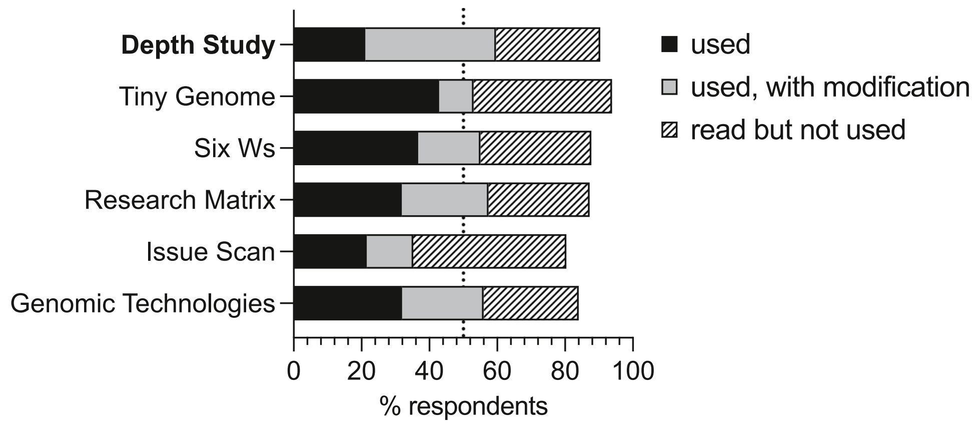

Fig. 1 Proportion of respondents who indicated interacting with each resource, either by using them in the classroom as written (black bars); using them in the classroom with modification (grey bars); or reading them (hatched bars)

related to the difficulty of the tasks and the need to modify resources for lower ability students. For example:

> "The high level of these resources was at times challenging". (DS18)

Likewise, many responses to the question "what else would you need to make the resources most helpful" centred on simplification, either of length, difficulty, or the instructions associated with the resources. For example:

> "Making tasks accessible to the full range of student ability and engagement". (LP5)

Outcomes for students

Teachers reported positive outcomes for students after they used the resources (Fig. 2). Most teachers agreed or strongly agreed that the resources were relevant and engaging (97%), were easy for students to follow (87%), and deepened student's understanding of genetic concepts (91%). There was also strong agreement that the resources supported the consideration of ethics and social issues (93%), developed higher order thinking skills (95%), and prepared students for future decision-making (87%). The lowest scoring variable related to preparing students for their final exams (66% agreement). There was a strong correlation between agreement that the resources helped students consider ethical and social issues and that they developed higher order thinking ($r=0.79$, $p<0.001$). Teachers who agreed that the resources developed higher order thinking were also more likely to agree that the resources deepened students' conceptual understanding ($r=0.63$, $p<0.001$) and prepared them for future decision-making ($r=0.64$, $p<0.001$).

Echoing the quantitative findings, the development of higher order thinking skills was frequently mentioned by teachers in the "most successful aspect" responses. This included references to development of analytical thinking, problem solving, and information processing skills. For example:

> "Good development of student analytical skills in Tiny Genome Task". (LP5)
> "Stretching student's thinking beyond 'right' and 'wrong' answers". (LP14)
> "Disease matrix forced students to process information". (DS2)
> "we had already been teaching them about mutations etc., but suddenly the light bulbs went on". (DS34)

Teachers also commented that the resources were interesting, relevant, and engaging for students, while also deepening their understanding of genetic concepts. They

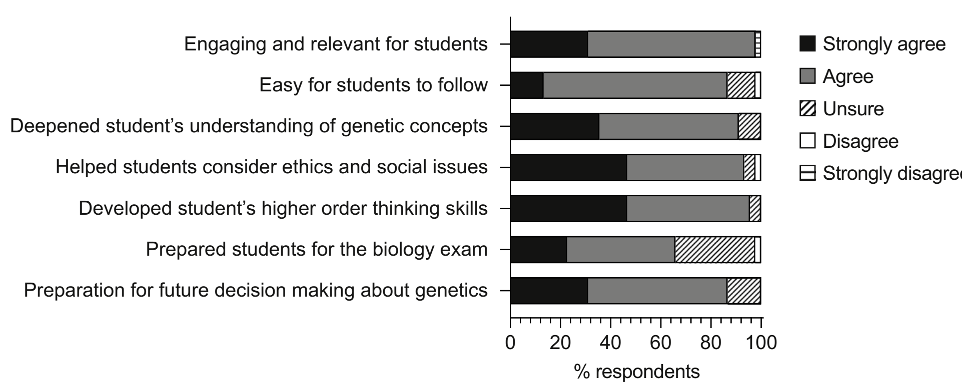

Fig. 2 Responses to questions regarding outcomes for students ($n=47$). For each statement, respondents selected either strongly agree (black bars), agree (grey bars), unsure (diagonally hatched bars), disagree (unfilled bars), or strongly disagree (horizontally hatched bars)

commented on the "current", "high tech" content, reflecting its development by a research institute. For example:

> "Current up to date material which engaged students and made them think". (DS20)

Respondents to the detailed survey also emphasised the relevance of the resources, including the importance of the connection with an MRI.

> "Many students rated it as the highlight of Biology. It was relevant to their lives, interesting and really useful for their understanding of genetics". (DS34)
> "I feel the link to a real genetics research organisation made it meaningful to the students". (DS38)

Outcomes for teachers

Most teachers felt that they had the background knowledge to use the resources (93%), and they also agreed that using the resources (as well as attending any associated TPD) increased both their background knowledge (96%) and their confidence in teaching genetics (90%) (Fig. 3). There was a significant positive correlation between agreement with increased knowledge and increased confidence ($r = 0.84$, $p < 0.001$). Respondents also indicated that they felt supported in teaching genetics (89%) and would likely use the resources again next year (91%). Only 44% agreed that the resources lightened their workload. Seventy percent of teachers indicated that the resources resulted in spending more time on social and ethical considerations. Mean weighted scores for this variable were higher among teachers who used the depth study ($M = 4.45$) compared to those who used only lesson plans ($M = 3.57$) [$t(51) = 2.01$, $p = 0.050$].

Teachers who agreed that the resources decreased their workload (44%) rated the resources more highly on multiple quality indicators compared to those who were unsure or disagreed with this statement. These data were supported by comments from teachers including:

> "…saved me a lot of time as I did not need to research suitable genetic diseases myself. The marking rubric and outline for the task were excellent". (DS8)
> "As students worked through scaffold at different pace, it allowed me to target support as needed". (DS19)

The greatest differences in mean weighted scores related to the resources being appropriately pitched ($M = 4.48$ vs $M = 3.77$, $t(51) = 2.80$, $p = 0.002$), deepening students' understanding of genetics ($M = 4.55$ vs $M = 4.00$, $t(43) = 3.27$, $p = 0.002$), and whether the teacher felt supported ($M = 4.57$ vs $M = 3.91$, $t(52) = 3.45$, $p = 0.001$). There was no significant difference in the number of resources used or modified between teachers who agreed that their workload was reduced with those who did not. These data were supported by teachers commenting that they found the amount of information overwhelming. For example:

> "Almost an overload of resources—picking and choosing which ones I would use and simplifying for the purposes of our task was a bit of a challenge initially". (DS8)
> "all was nice but it took time for us teachers to get on top of all the info provided including knowledge on the genetic diseases". (DS33)

There were no significant differences in mean weighted scores for any of the variables when comparing teachers who attended TPD workshops and those who did not. However, in open comments, multiple teachers suggested that additional TPD opportunities, school support, or time for TPD would be needed to make the resources most helpful. Indeed, comments relating to time restraints were common across both the challenges and needs open questions, both in relation to workload and also teaching time. For example:

> "we just do not have that amount of time (even in the depth study …) to do all that work". (DS15)

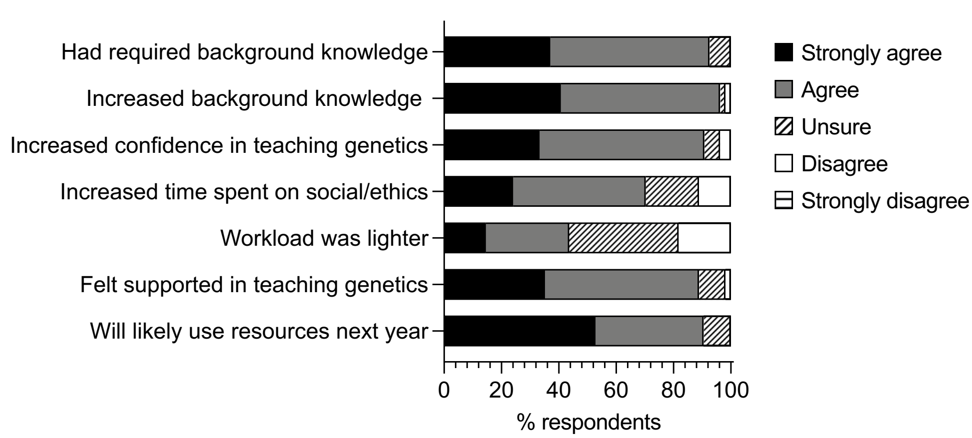

Fig. 3 Responses to questions regarding outcomes for teachers ($n = 54$). For each statement, respondents selected either strongly agree (black bars), agree (grey bars), unsure (diagonally hatched bars), disagree (unfilled bars), or strongly disagree (horizontally hatched bars)

Teacher outcomes identified in the "most successful aspect" responses related to feeling supported, and having access to answers and reference materials. The nine teachers who responded to the detailed depth study-focussed survey identified ways in which the resources differed from their usual teaching approach. They described taking a more student-driven approach with opportunities for active learning, as well as placing a greater emphasis on ethics. For example:

> "the group discussions were great. I usually do this stuff ad hoc. But the cards and other stimulus were great. To make the discussion happen and everyone had to be in it". (DS30)
> "I wouldn't normally use role play in my classroom but I think it worked rather well so I'm planning to do it again". (DS36)

Discussion

A suite of resources was developed for teachers of senior biology that supported the teaching of human genetics and genomics and associated SSI within the redesigned senior biology syllabus in NSW, Australia. Resources included a student-led inquiry task or "depth study", and modular, adaptable lesson plans. These were widely accessed, and implemented by many teachers beginning in 2019. The 56 teachers who responded to an evaluation survey reported that the resources were high quality, easy to use and adapt, and well-aligned with the syllabus. Teachers felt that using the resources supported their students to understand genetic concepts, consider social and ethical issues, and develop higher order thinking skills. Teachers also reported feeling supported in their teaching of genetics and increases in their confidence and background knowledge. In open comments, respondents emphasised the engaging, relevant, and authentic nature of the resources. Suggestions were also made to include options to simplify the resources, to make them more accessible to students of differing ability levels.

Teachers valued that the resources were both interesting and engaging but also well-aligned with the syllabus. The link with the MRI was directly mentioned in one comment as making the learning meaningful to students, and the currency and relevancy of the resources were also appreciated by multiple teachers. This dynamic has been framed as "bridging communities of practice" and has been shown to have benefits for students, teachers, and scientists (Tytler et al. 2015, 2017). Medical research institutes (MRIs) and universities are well placed to support secondary teachers with current, relevant, and authentic contexts for teaching scientific concepts (Haury and Nehm 2012). In the case of these resources, educators employed by the MRI served in the role Tytler et al. (2017) call "brokers", bridging the gap between the scientific developments in clinical genomics and the requirements of high school curriculum and assessment.

Teachers reported that the resources enhanced students' understanding of genetic concepts as well as their higher order thinking skills. The depth study aligns closely with the SSI teaching and learning (SSI-TL) framework of Sadler et al. (2017), in which a contemporary issue is used as the stimulus for exploring science content as well as socioscientific reasoning. SSI-based approaches to science education specifically focus on critical thinking skills, but have also been demonstrated to support effective development of conceptual knowledge (Sadler et al. 2016). The depth study also aligns with frameworks of inquiry-based learning, particularly elements of critique and evaluation as emphasised by the National Research Council (2012). Some elements of inquiry are mandated by the syllabus requirements for depth studies (NSW Education Standards Authority 2017) including students' choice in developing and evaluating their own inquiry questions and communicating the results of their investigation. There is recognised synergy between SSI- and inquiry-based approaches (Evans and Dolin 2018), and they have previously been combined to enhance student engagement with science for citizenship (Amos and Levinson 2019). Supporting student argumentation in SSI and open inquiry are two areas that have been identified as important for targeted professional development (Carson and Dawson 2016; Gulamhussein 2013). Teachers' suggestions of additional professional development to support implementation of these resources are consistent with this identified need.

In addition to increases in background knowledge and confidence, teachers indicated shifts in their teaching approach as a result of using the resources, such as the inclusion of more active learning and class discussions. However, not all teachers agreed that they spent longer on social and ethical issues than they would have otherwise. It was not clear if this reflected a lack of focus on these aspects of the resources or a suggestion that responding teachers already valued and prioritised this aspect of teaching. Teacher confidence and preferences are known to vary widely in this area (Aivelo and Uitto 2019); thus, a potential future direction for research might be to examine the extent to which teachers were able to support and assess the development of socioscientific reasoning. Although uptake of the ethics-focussed lesson plan was lower than others, the depth study focused on balancing risks and benefits and supporting claims with evidence, which are key components of socioscientific reasoning (Karahan and Roehrig 2017), and is also found in ethical thinking frameworks (Buntting and Jones 2020).

Some findings from this evaluation may be transferrable to future interactions between scientific institutes or professions and teachers. Specifically, teachers confirmed that they value modular, curriculum-aligned resources and require adaptability to a range of student ability levels. Student engagement and interest is prioritised by teachers, and inclusion of some simplified ready-to-go versions of resources may increase their effectiveness and usage. Teacher workload is already high and bound by time restraints, and some teachers reported feeling overwhelmed by the volume of resources. Clarity should be a focus for both teacher- and student-facing resources. Although there were no significant differences found in this evaluation between teachers who attended teacher professional development and those who do not, multiple teachers expressed a need for time to familiarise themselves both the content and resources and TPD may help to fulfil this requirement.

Limitations of the evaluation methodology include the self-selecting group of participants and survey responders. Teachers who accessed the resources may represent those who would be most likely to value them, and those who used them most successfully may have been more likely to respond to the survey. The strengths and weaknesses of the resources identified by the evaluation are likely to represent genuine enablers and barriers to effectiveness. Teacher outcomes were self-reported, and student outcomes were evaluated only via their teachers' perspectives, so social desirability bias cannot be ruled out. Future directions for evaluation of such resources could include direct measurement of student genetic literacy and socioscientific reasoning. If the required resources were available to support willing teachers, validated scales could be administered for each of these (Carver et al. 2017; Romine et al. 2017; Todd et al. 2017).

Conclusion

The resources developed relate to real-life applications of genetics and promoted active learning and authentic inquiry into the risks and benefits of genomic medicine. The resources aligned with the NSW biology syllabus as well as the three types of knowledge considered essential for genetic literacy (conceptual, sociocultural, and epistemic). Using a program logic approach, our evaluation established that the resources met the intended aims of producing high-quality and effective learning resources. The resources increased teacher confidence and knowledge and supported teachers to develop student genetic literacy, including higher order thinking skills, consideration of social and ethical issues, and deeper understanding of genetics concepts. Suggested improvements such as the inclusion of simplified options and additional teacher professional development may improve teacher familiarity with both the content and the resources. This would further enhance the resources' usefulness and impact on the genetic literacy of Australian senior biology students.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12687-021-00550-3.

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Author contribution Lauren McKnight and Bronwyn Terrill developed the resources. All authors contributed to the conception and design of the evaluation. Data collection and analysis were performed by Angela Pearce, Lauren McKnight, and Bronwyn Terrill. The first draft of the manuscript was written by Lauren McKnight and all authors reviewed the manuscript. All authors read and approved the final manuscript.

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Data availability Resources evaluated in this paper are available from www.garvan.org.au/kccg-teachers.

Code availability Not applicable.

Declarations

Conflict of interest Lauren McKnight is currently serving on the council of the Science Teachers Association of New South Wales, Australia (STANSW). B.T, A.P., A.W., and M-A.Y declare no competing interests. All educational materials and professional development were provided free of charge to teachers.

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