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Case Study

Case Study: CRISPR 101 – a novel online learning course harnessing innovative ways to teach a complex biomolecular technology

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Complex biomolecular technologies revolutionise scientific research. Fully embedding scientific advances in the community requires innovative ways to educate learners on the molecular foundations upon which these technologies are based. In this case study, we present the conception and design of Walter and Eliza Hall Institute of Medical Research (WEHI's) inaugural wholly online learning course focussed on explaining the revolutionary genome-editing technology, clustered regulatory interspaced palindromic repeats (CRISPR). Utilising WEHI's strength in bringing science educators and world-leading CRISPR scientists together, we designed a multimodal online resource that introduces learners, without an extensive background in either science or genome editing, to the fundamental concepts of CRISPR technology. Using the online course creation tool, Articulate 360, we guided learners through three modules containing targeted lessons designed to focus on specific learning outcomes. Integrated videos, research articles, interviews, and other resources, allowed for self-paced learning that met various learning style needs. The extensive resources provided opportunities to delve deeper into the content for advanced learners. The effectiveness of the course, evaluated with survey responses collected upon completion of the course, highlighted the ease of use and functionality of the course, and an increased understanding of CRISPR technology after course completion. We anticipate future online learning course development to showcase complex molecular technology that will be valuable for tertiary education, as well as for those in the wider community interested in understanding important advances in biomedicine.

Introduction

The pivotal discovery of the molecular structure of DNA by Rosalind Franklin in the 1950s started a genetic revolution that today allows scientists to use specific and precise genome-editing tools, including Clustered Regularly Interspaced Palindromic Repeats (CRISPR)-CRISPR-associated protein (Cas9) technology (hereafter referred to as CRISPR) [1]. Modern molecular tools and technologies greatly increase the speed of scientific discovery, providing novel therapeutic avenues to combat disease. Technological advancements highlight a need to easily convey their underlying biochemical principles to ensure correct application of the technologies. Here, we describe the development of a novel online learning course as an innovative way to teach learners about genome editing with CRISPR. For this, we utilised the combined expertise of science educators and world leading CRISPR experts present at the Walter and Eliza Hall Institute of Medical Research (WEHI) to create a wholly online, interactive learning course to convey the

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principles of CRISPR to learners without extensive knowledge in science or genome editing. Using the online course creation tool *Articulate 360* (Articulate Global LLC, New York, U.S.A.), we created scaffolded lessons on DNA, genome editing and CRISPR in a multimodal course. We anticipate that online learning courses, due to their flexibility and ease in use and design, will complement traditional lab-based teaching of molecular techniques, foster engagement with the public about technologies and research, and further address the need for interactive remote learning which has been exposed by the COVID-19 pandemic [2,3].

Methods

The creation of this novel CRISPR 101 online learning course facilitates self-directed learning by incorporating a fully automated wholly online delivery of the course content. This is reflected in the design of the learning outcomes which allowed for a scaffolded approach by introducing content in earlier lessons that is needed to understand more advanced lessons. Furthermore, this scaffolding approach helps demonstrate to the learner that all topics are integrated and that the contents of the course are connected. In the first instance, we designed the course to target an audience with no or limited scientific background to engage the wider community with scientific technologies and to educate staff and students with sophisticated technologies performed at the institute. The online course creation tool *Articulate 360* (Articulate Global LLC, New York, U.S.A.) allows for a flexible design to cater for different student learning styles with a focus on knowledge transfer through digital technology. To create this novel online course and to nurture an innovative way to teach a complex biomolecular technology, we harnessed WEHI's strength in both education and research.

The five stages of design

Pedagogical and content knowledge (PCK) is paramount to successful learning outcomes [2,4]. Each learning objective should be accompanied by meaningful pedagogical methods, especially in a technology-driven environment [5]. This is especially true in biological sciences as new concepts arise and new complex technologies are being developed [6–8]. At WEHI, we are in strong position to bring science educators and scientists together to utilise our expertise by combining effective pedagogical techniques and deep content knowledge that enables the design of a novel online learning course centred around the learner's needs (Figure 1). In this regard, WEHI science educators bring expert knowledge about scientific teaching practices (pedagogical knowledge) together with WEHI lab-based scientists who serve as subject matter experts (SMEs) (content knowledge). This facilitates designing learning tasks to address the specific needs of the learner's cohort.

We followed a five-stage design approach for the creation of *CRISPR 101* (Figure 1) using iterative cycles, which is based on the successive approximation model (SAM) [9] allowing for a flexible design process utilising SMEs. This allowed for an incremental process and ensured the continued integration of novel pedagogical methods and evolving content knowledge. The first step involves the conception of the course highlighted by the need to (1) find innovative ways to educate staff and students on the biomolecular technologies used at WEHI, and (2) to engage the wider community with scientific technologies aiding therapeutic avenues. We identified learners without extensive knowledge of science or genome editing as target audience for this course, and we also aimed to generate a course that would be applicable to educate the community on technologies used in modern bioscience. The design phase (step 2) ensured a scaffolding approach, as syntactic knowledge on the basics of DNA is required to learn and understand more advanced content on editing DNA. When building the course (step 3) we included different learning approaches to cater for various learning styles, defined as how individuals approach tasks and process information when learning [10]. According to the VARK model, the predominant learning styles are visual, auditory, reading, writing and kinaesthetic [11,12]. To accommodate these styles, we included articles to read, videos to watch, podcasts to listen to, and interactive tasks for kinaesthetic learners. Learners choose a combination of learning approaches to assist in their understanding of the material (Figure 2). After completing the first steps, we have initially launched the course internally within WEHI (step 4). In order to receive feedback and assess the effectiveness of the course, participants of the course were asked to complete a short voluntary survey (step 5) upon completion of the course. Survey results informed modifications and future course design. At all design phases, close liaison between science educators and SMEs ensured the integration of content and pedagogy.

The learning outcomes follow the history of CRISPR development

Identifying and formulating learning outcomes was guided by the principles of Bloom's taxonomy, and the updated version by Krathwohl allows for the inclusion of action-based verbs to indicate that learning is an active process [13]. Instructional design software as harnessed in *Articulate 360* further re-emphasises those action-based verbs. The

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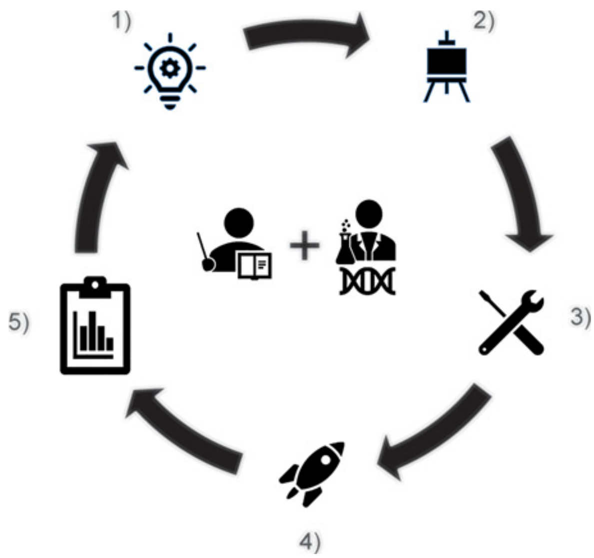

Figure 1. The five phases to create the novel online learning course 'CRISPR 101'
The course was designed in five phases based on the SAM model. (1) Conceiving the idea and concept by bringing WEHI's science educators and world-leading CRISPR scientists (SMEs) together to develop the framework for the course. (2) Design of course content based on discussion with the SME. (3) Implementation of the course content into the online course creation tool 'Articulate 360' and creating all building blocks. (4) The course is launched and advertised to the initial cohort it was designed for. (5) Evaluation of the course by asking learners to participate in a survey. The arrows indicate that the design process is an ongoing iterative process with evaluation and feedback informing course design.

course presented here mainly integrates the Bloom levels *Understand* and *Apply* as they are particularly important for molecular bioscience in the context of a highly specialised medical research institute, where students are required to understand and apply modern scientific technologies. Within the CRISPR 101 online learning course, each lesson consists of three main learning outcomes, (e.g. 'Understand how CRISPR was adapted to become a genome editing tool.') that use the above mentioned Bloom's action verbs.

Collection of survey data to assess the effectiveness of the course

To assess the effectiveness of the novel *CRISPR 101* online learning course, we designed a survey to capture feedback from course participants upon completion. Questions were based on the Kirkpatrick model [14] while keeping in mind that there is no formal assessment for this course. Instead, voluntary knowledge checks have been used throughout to assist with learning. Questions for the survey are formulated to address learners understanding of course content, how well information was communicated, the use of the platform itself, and what learners enjoyed most about the course. We used the SurveyMonkey (Momentive Inc., San Mateo, California, U.S.A.) interface to gather survey data.

Findings

We successfully completed the five design phases (Figure 1) and initially launched the course internally into WEHI's community. While the course has since become publicly available (www.wehi.edu.au/education/learning-hub), findings in this manuscript contain data from WEHI's internal launch. This is WEHI's inaugural wholly online learning course showcasing a complex molecular technology and represents a free interactive online learning resource introducing CRISPR-Cas9 technology to the wider community.

The composition of *CRISPR 101*

We included three modules in the course (Basics of DNA, Introduction to Genome Editing, Genome Editing with CRISPR), and the course comprised a total of 14 lessons. Learners follow a self-directed learning approach, with the course content completed in 2–5 h, depending on interaction with included resources and prior knowledge. Utilising the *Articulate 360* (Articulate Global LLC, New York, U.S.A.) interface technology, major design elements to aid learning include click-through images, interactive images, videos, and voluntary knowledge checks (Figure 2).

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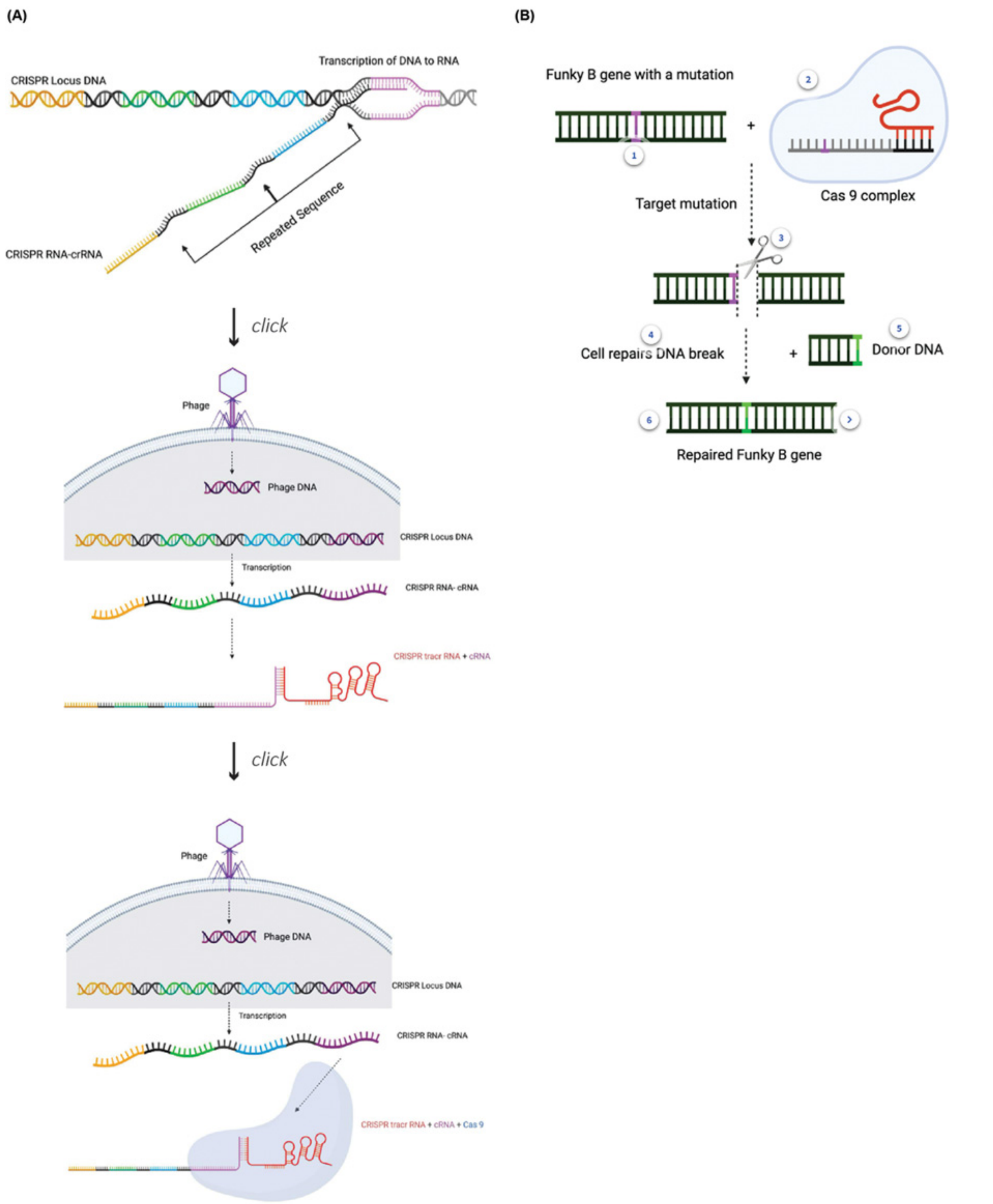

Figure 2. Major design elements highlighting the functionality of the course

Throughout the course design features were used as learning activities to engage learners with the content. (**A**) A click-through image introducing the learner to new content step-by-step at the learner's pace, e.g. the introduction of the bacterial CRISPR locus as shown here. (**B**) An interactive image to engage the learner with the content and introducing more detailed information at the learner's pace, e.g. a hypothetical gene editing experiment as shown here. (**C**) Videos to break up content and to convey information in an easily comprehensible manner, e.g. on DNA cloning as shown here (**D**) Voluntary checks have been included at the end of each lesson to help the learner recapitulate the learned content, that amongst other contain multiple-choice questions as shown here.

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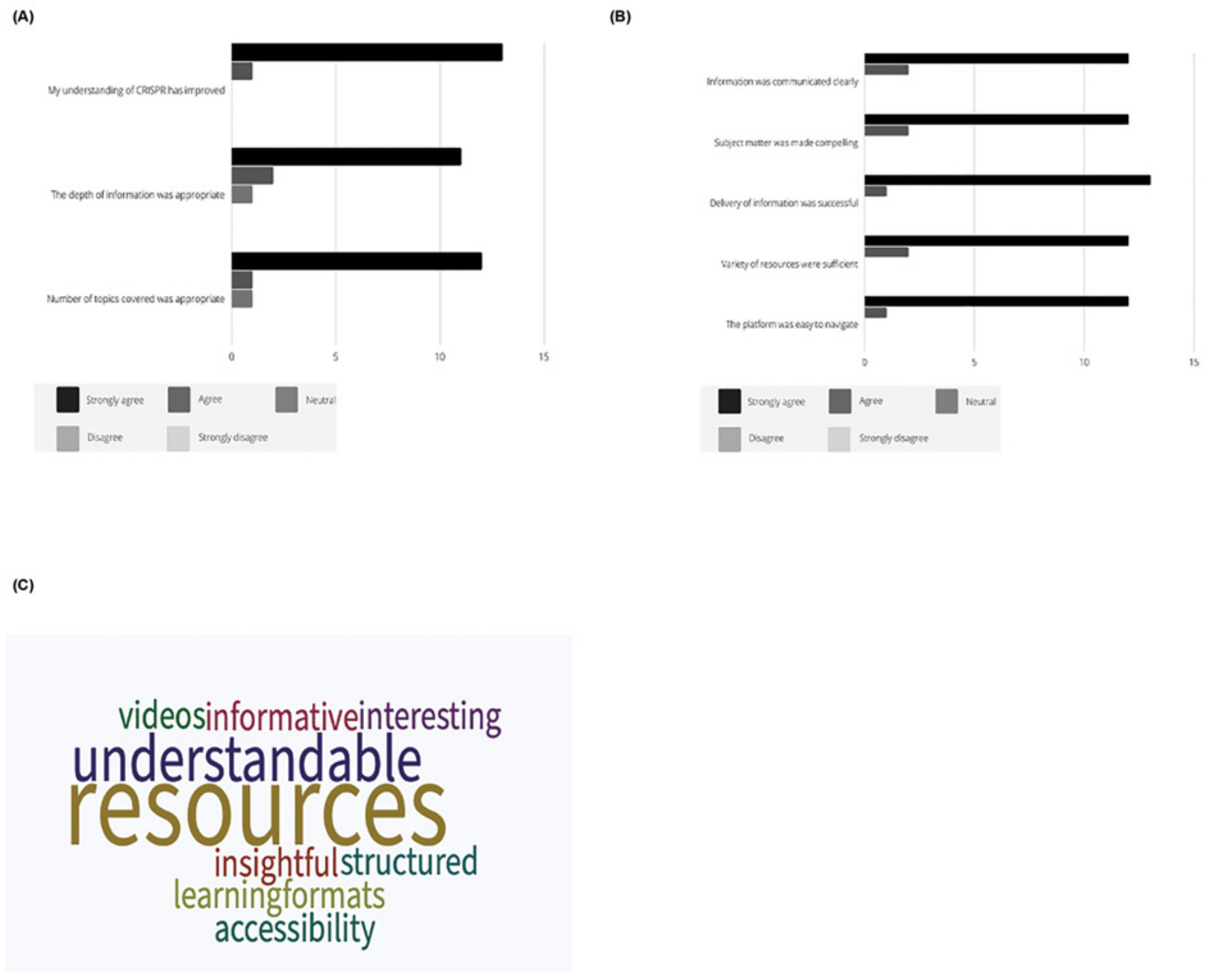

Figure 3. Visual presentation of survey data for course evaluation

Participants of the course after a preliminary internal launch were asked to fill out at a survey at completion of the course. (**A**) Bar chart showing that learners reported an improved understanding of CRISPR technology, and that the depth of information and number of topics covered met their learning needs. (**B**) Bar chart reporting answers of respondents indicating that information in the course was communicated effectively and made interesting with the range of resources supplied. Learners also indicated that the platform was easy to navigate. (**C**) A word cloud summarising free-text feedback of respondents highlighting the functionality (e.g., 'resources') and technology (e.g., 'understandable') of the course. Survey results have been collected via SurveyMonkey (Momentive Inc., San Mateo, California, U.S.A.), $n=14$.

Click-through images are of particular importance for the learner as new content is revealed upon active engagement by the learner, revealing a new image upon click, thereby introducing content step-by-step at the learner's pace. Similarly, interactive images allow for studying at the learner's pace as additional content is revealed by clicking on the plus-symbols of the image (Figure 2B). Voluntary knowledge checks are also used by a similar resource introducing complex scientific technology ('CryoEM 101', University of Utah), and represent a powerful to reinforce the learned concepts. This is also further supported by additional resources, such as articles, research papers or interviews with scientists. There is no formal assessment for this course and learners engage with the content depending on their individual needs and scientific background.

Iterative design process

The strength of our design approach is the collaborative nature by including SMEs and course testers external to the design team in all stages of the course design (Figure 1). Together with using the Articulate design interface, this allowed for rapid development of individual lessons/modules, similar to computer software prototyping [15] that can

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be evaluated by SMEs and tested by a selected cohort of people providing immediate feedback. Indeed, the course was generated by creating one lesson at a time allowing for creative design by finding the best ways of using each design element (Figure 2) to convey a particular content. Once a module was finished, a current version of the course was shared via Review 360 (Articulate Global LLC, New York, U.S.A.) with external testers. Using this process, we were able to quickly adjust the overall language used to avoid scientific jargon keeping the target audience in mind. Future iterative cycles are warranted to include feedback from course participants further improving content and design features of the course.

Course participants have increased knowledge of CRISPR technology

For course evaluation, we launched the course internally at WEHI. Of note, we relied on voluntary course enrolment, and there was no incentive provided to either complete the course or the survery. For the present study, survey responses from 14 self-selected participants were collected upon completion of the course as part of our initial course launch. Those participants are all part of WEHI (four professional services staff, six research assistants, three students, one participant unspecified) due to the nature of the internal launch. Evaluating the results revealed success in conveying the learning outcomes and understanding of the material, with 100% of course participants reporting that they have increased knowledge of CRISPR technology, and 90% agreeing that the depth of information covered met their learning needs (Figure 3A).

The survey results highlighted the ease of use of the course platform and the effectiveness in which to communicate complex topics; 100% of respondents agreed that the course was easy to navigate, the information was communicated clearly, and the subject matter was made compelling (Figure 3B).

Finally, we generated a word cloud to summarise free-text replies of course participants about the best features of the course. This word cloud highlights the functionality of the course and the use of resources as major benefits of the course (Figure 3C). Key words included 'Understandable' and 'Resources' as the most common, with 'videos, informative, interesting, insightful, structured and learning formats' also mentioned frequently.

Contribution to the field

With increasing uptake of genome-editing technologies to cure diseases, and the recent Nobel Prize being awarded to the Emmanuelle Charpentier and Jennifer Doudna, who first demonstrated that CRISPR can be used to edit DNA [16], this novel online learning resource will be invaluable in demystifying an important tool in the modern biomolecular toolbox.

Conclusion

The newly developed CRISPR 101 online learning course takes a novel approach to explaining the history and applications of CRISPR technology. While other public resources explaining CRISPR technology exist ('CRISPR-Cas9 Mechanisms and Applications' by HHMI BioInteractive, Howard Hughes Medical Institute, Chevy Chase, MD, U.S.A.; 'CRISPR made simple' by Innovative Genomics Institute, Berkely, CA, U.S.A.), the self-paced approach and careful content planning with a student-centred view, allows our newly developed CRISPR 101 online learning course to be useful for those with a limited science background, as well as students who are new to CRISPR and genome editing. Showing the flexibility of our design approach, this course can be modified to cater more advanced users in future versions of the course. Importantly, subsequent future interrogation of the course effectiveness is warranted by performing structured investigation to include data gathered following the public launch of the course. In summary, the generation of this resource demonstrates a proof of principle that e-learning resources can be used to explain complex concepts in molecular bioscience.

Summary

- **The importance of the field**: Complex biomolecular technologies are being increasingly used in scientific research highlighting a need to find innovative ways to educate learners on the molecular background of those technologies. Due to their flexibility and ease in use and design, online learning courses offer great potential to complement traditional lab-based teaching showcasing biomolecular technologies.

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- **A summary of the current thinking**: Recent advancements and breakthroughs in molecular technologies, including the revolutionary use of CRISPR-Cas9 for genome editing, have accelerated scientific research and therapeutic outcomes. The complexity of these technologies highlights a need to develop innovative ways to educate learners on the molecular background while further harnessing remote online learning tools.
- **Comments on future directions**: The novel online learning course 'CRISPR 101' presented here was designed to address the need to educate learners with a limited background in science or genome editing. Future courses will have an increased focus on lab-specific applications, to educate research higher degree research students and scientific staff using those complex biomolecular technologies. We anticipate that the use of novel online learning courses will be increasingly used to (1) engage with the wider community and (2) to complement traditional lab-based teaching.

Competing Interests
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Author Contribution
M.P., N.C., M.J.H. and K.B.O. designed and created the course, and drafted this manuscript.

Ethics Approval
The current study is considered low risk and qualifies for exemption from ethical review.

Declaration of Interests
N.C., M.J.H. and K.B.O. are employees at WEHI. M.P. is an honorary staff member at WEHI. WEHI is a not-for-profit organisation.

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Abbreviations
Cas, CRISPR-associated protein; CRISPR, clustered regulatory interspaced palindromic repeats; SME, subject matter expert; WEHI, Walter and Eliza Hall Institute of Medical Research.

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