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Teaching the Genome Generation

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 Scientia

TEACHING THE GENOME GENERATION

Since the release of the first human genome, our understanding of genetics has grown significantly. However, keeping up with developments in the field can be overwhelming for students, and even teachers. **Dr Charles Wray** of The Jackson Laboratory has created a unique program, 'Teaching the Genome Generation' or 'TtGG', to address this issue. TtGG aims to inform and train high school teachers, and in turn, increase student literacy in genomics and interest in STEM careers.

Society Needs Robust Genomics Education

Genetics is the study of heredity, or how the characteristics of living organisms are transmitted from one generation to the next through DNA. Genetics research typically involves the study of a specific gene, limited numbers of genes, or parts of genes. Genomics, on the other hand, investigates the entirety of an organism's DNA – both genes and non-coding DNA – called the genome.

The field of genomics has exploded in recent times. In 2003, after 13 years of hard work on the part of scientists across the globe, the Human Genome Project was completed. This project was a joint venture to determine the exact order of all the DNA that makes up the human genome. Now, 16 years after the release of the first human genome, and driven by significant technology developments in high throughput DNA sequencing, one genome became dozens, hundreds, thousands and now hundreds of thousands of genome sequences. Not a month goes by without the publication of new human genome sequences.

Indeed, as technology and computing techniques improve, the study of genetics and genomics has advanced by leaps and bounds. With such advancement in genomics, comes incredible levels of complexity. While both general and scientific media try to cover and explain the developments, confusion can arise. Genomic complexity can confound learners at any level, including high school students. Nevertheless, many of the foundational concepts are understandable, if they are explained and taught correctly. Unfortunately, many educators are not trained or equipped to teach basic genomics.

To address this, Dr Charles Wray of The Jackson Laboratory and his colleagues have created a special professional development program called 'Teaching the Genome Generation', or 'TtGG'. TtGG provides training to teachers so they can improve how they teach genomics at the high school level. The program helps educators to stay abreast of genomics research and integrate up-to-date content into their lessons. In commenting on TtGG, Dr Wray explains, 'we are working hard to modernise genetics and genomics education at



the high school level, and we're doing this by providing lessons, teaching materials and resources for teachers. We seek to make genetics, genomics, bioinformatics and bioethics exciting for students and teachers, and in so doing, foster STEM careers.'

TtGG – An Overview

In a paper of 2018, Dr Wray and his co-authors describe TtGG as 'a high school teacher professional development program that provides educators in the New England region with the tools they



need to prepare their students for life in the genomics era.' The program is directed by The Jackson Laboratory, with financial assistance from a National Institutes of Health, Science Education Partnership Award.

The program consists of summer professional development courses that integrate instruction in molecular genetics laboratory techniques, bioinformatics and bioethics. The program empowers teachers, and encourages them to pass on their knowledge, skills and practical techniques to their students. The professional development course sets aside a substantial amount of time for discussion and lesson plan development. Teachers are also supported throughout the subsequent implementation phase. Finally, to assist with roll-out, teachers are provided with customised mobile laboratory kits, supplies and reagents and extensive curriculum resources.

As was mentioned at the outset, our understanding of genomics is forever changing, especially as new developments come to light. In recognition of this, TtGG provides continual access to updated genomics education resources through an online TtGG repository. This includes laboratory protocols, bioethics and bioinformatics exercises, instructional videos and external content such as news articles, abstracts of scientific papers and suggested books. This helps teachers to keep abreast of the latest developments and to ensure they are passing on the valuable knowledge to their students.

Molecular Genetics, Bioinformatics and Bioethics

Practical skills and hands-on learning is very much the focus of the **molecular genetics** component of TtGG. Through a series of six activities, teachers gain relevant practical skills and techniques. In fact, they perform the very experiments they will later implement in the classroom setting, so they can be confident when guiding their students. These experiments involve many of the techniques that genetics researchers routinely use, such as micro-pipetting, DNA extraction, PCR (Polymerase Chain Reactions), restriction enzyme digestion, gel electrophoresis DNA sequencing and sequence analysis.

Bioinformatics, on the other hand, is the science of collecting, analysing and storing biological information. Bioinformatics is an essential and rapidly expanding area of science with wide-reaching implications, particularly in genomics. However, at the high school level, it is a very challenging topic to teach. As a result, many secondary school teachers avoid including it in their learning activities. Through a series of case studies and exercises, the bioinformatics component of TtGG provides teachers with hands-on experience using genomics databases and the needed know-how to effectively engage their students in bioinformatics. For example, one exercise encourages participants to use relevant databases to research the genes associated with familiar diseases.



And finally, TtGG aims to assist teachers with their **bioethics**-related learning activities. Bioethics is an interdisciplinary field of study that explores the moral and ethical issues surrounding biological research and its implementation in the real world. Teachers are given specific training on how to cover related issues in their teaching, with foci including reproductive genetics, personalised medicine and public policy. There are six ethics lessons during the course that utilise active learning strategies to explore these topics.

How TtGG Translates in the Classroom

After having received this training, as one may expect, teachers are itching to apply their new skills and knowledge to enhance learning in their respective classrooms. This is very much reflected in the feedback received thus far. As highlighted in Dr Wray's 2018 paper, over the past three academic years (2014/15, 2015/16 and 2016/17), 75% of teacher-participants have implemented the TtGG lessons in their classrooms. These are encouraging signs, and it

demonstrates the real-world value of the instruction received.

Of particular note are the sessions in which students complete authentic laboratory exercises, using the equipment supplied by The Jackson Laboratory. Using real-world resources and conducting authentic experiments very much enriches student learning. Given that teachers have actually performed the experiments themselves and know what to expect, they bring these sessions to life. Referring again to the feedback received thus far, the data has indicated that students are deeply engaged and learning new skills in TtGG laboratory sessions.

TtGG's Widespread Impact

In 2018, Dr Wray and his team reported the highest number of school implementations – some 144 schools, of which 129 were public. 149 teachers have been involved in the program across the New England region. These teachers, equipped with new-found knowledge and teaching strategies, have made an impact on over 7000 students over the course of

202 implementations. Many of these implementations have occurred in schools where more than 20% of the students are members of groups underrepresented in science. This growth is set to continue.

The TtGG team attributes the program's success to several factors: (1) they hired TtGG-dedicated staff members to support and manage classroom implementation; (2) they have incentivised implementing of the curriculum with a one-time \$500 stipend; and (3) they have increased teacher communication and interaction throughout the academic year, including regional teacher-participant meetups, participation in other regional high school teacher events and publication of a monthly bulletin that highlights genomics and bioethics news. These features will continue to be a regular feature of TtGG.

The Future of TtGG

Of course, Dr Wray and his colleagues will continue to make improvements to the program. For example, they want to find a way to make bioinformatics more accessible and improve implementation rates for that component of the program. They also want to understand the impact of TtGG on individual teaching practices and on participants' self-efficacy in teaching genomics, and they have suggested further strategies to that end.

Nevertheless, TtGG continues to enthuse and equip teachers to include or improve genetics and genomics education. This will have an impact on student learning in STEM, the genomics industry, and the future advancement of genetics and genomic research. This is exciting news because these fields of study are poised to revolutionise healthcare, have high career development potential, and ultimately, are very intriguing fields of study. Without a doubt, students will carry this enthusiasm into their further studies and employment in related fields.



Meet the researcher

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Dr Charles Wray received his PhD from Yale University in 1994. After postdoctoral work across several institutions, he joined The Jackson Laboratory first in 1999 and then again in 2014. He currently serves there as Director of Courses and Conferences, and teaches courses covering genetics, genomics and bioinformatics. Within the field of evolutionary biology, his research has centred on using molecular biology to investigate evolutionary and ecological issues. He focuses the majority of his time, effort and resources on science outreach and education. In fact, he has been a science educator and outreach director since 1986, teaching across all levels of education. Most recently, he created 'Teaching the Genome Generation' (described herein) and launched 'Big Genomic Data Skills Training for Professors' – an effort to train professors from small colleges and regional universities in curricular integration of genomic data analysis into undergraduate courses. TtGG aims to increase students' genomic and genetic literacy by training and equipping high school teachers.

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FURTHER READING

KM LaRue, MP McKernan, KM Bass, CG Wray, Teaching the Genome Generation: Bringing Modern Human Genetics into the Classroom Through Teacher Professional Development, Journal of STEM Outreach, 2018, 1, 2.



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