SHORT COMMUNICATION

Volume 18 No. 2 2026

DOI: 10.21315/eimj2026.18.2.11

ARTICLE INFO

Submitted: 19-07-2025
Accepted: 06-09-2025
Online: 30-06-2026

An Experiential Online Learning Module on Genetics and Genomics for Multidisciplinary Undergraduate Students

Marahaini Musa[1], Sarina Sulong[1], Nazihah Mohd Yunus[1], Aziati Azwari Annuar[1], Ahmad Aizat Abdul Aziz[1], Wan Nur Amalina Zakaria[1], Zilfalil Alwi[1], Mohd Zaki Hussin[1], Kumitaa Theva Das[2], Siti Nurbaya Mohd Nawi[3]

[1]*Human Genome Centre, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, MALAYSIA*

[2]*Institute for Research in Molecular Medicine (INFORMM), Universiti Sains Malaysia, Pulau Pinang, MALAYSIA*

[3]*Department of Internal Medicine, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, MALAYSIA*

To cite this article: Musa M, Sulong S, Mohd Yunus N, Annuar AA, Abdul Aziz AA, Zakaria WNA, Alwi Z, Hussin MZ, Das KT, Mohd Nawi SN. An experiential online learning module on genetics and genomics for multidisciplinary undergraduate students. Education in Medicine Journal. 2026;18(2):145–156. https://doi.org/10.21315/eimj2026.18.2.11

To link to this article: https://doi.org/10.21315/eimj2026.18.2.11

ABSTRACT

Teaching genetics and genomics to multidisciplinary undergraduate students presents challenges due to their varied academic backgrounds, particularly among non-science majors. To address this, YOUnique: From Genes to Gen (Genomics) was developed as an interactive online module introducing fundamental concepts through experiential learning. This module was delivered during the Live Inclusive Fulfilling Experience (LIFE) Programme, a two-week online summer programme offered by Universiti Sains Malaysia (USM). The YOUnique Genomics module aims to build scientific understanding, encourage ethical reflection on emerging genomic technologies, such as gene editing and precision medicine, and foster empathy towards individuals with genetic conditions. It integrates multimedia content, facilitator-led sessions, group discussions and hands-on activities exploring heredity, gene–environment interactions, epigenetics, and ageing. Student feedback indicated strong satisfaction with the module. Most participants strongly agreed that the module was useful, well organised and level appropriate, with activities described as enjoyable (96.1%) and facilitators praised for being knowledgeable, and engaging. Learners found the module relevant to their lives (98.1%) and appreciated the interdisciplinary exposure. Despite some participation barriers, such as Internet issues and personal commitments, students reported enhanced understanding of genetics, and genomics. Word cloud analysis further indicated an understanding of core genetic concepts alongside awareness of real-world applications and ethical issues. The YOUnique Genomics module demonstrates a dynamic, inclusive approach to genetics education across disciplines.

Keywords: *Genetics, Genomics, Education, Virtual learning, Multidisciplinary*

CORRESPONDING AUTHOR

Marahaini Musa, Human Genome Centre, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia

Email: marahaini.musa@usm.my

INTRODUCTION

Genetics is the branch of science concerned with the study of inheritance, the genes underlying it and their functions, while genomics is the study of the entire genome and the corresponding data generated from it (1). Genomics provides grounds for a greater understanding of the implications of genetic makeup for our health, particularly for diseases and conditions with multifactorial causes (2). Notably, genetic and genomic information is vital for understanding disease risk, including diabetes and cancer, as well as susceptibility to infections such as COVID-19 (3, 4). In-depth knowledge of genetics and genomics supports the development of precision medicine, underscoring the importance of educating the public about their roles in people's lives (5). This will help the public make informed healthcare decisions for themselves and their families (6).

In general, genetics is an important specialised subject in science. Literacy in this subject provides an essential foundation for students' learning for further advanced courses and employment (7). Despite this, educating students in genetics and genomics is often constrained by limited resources and the inherent complexity of these subjects (8).

Given the barriers to engaging learners from diverse academic backgrounds in genetics and genomics, impactful learning approaches have been implemented across institutions. The transformation from passive, mainly lecture-based, minimal-interaction learning to interactive learning sessions has the potential to benefit lower-achieving learners the most—it also enhances students' overall learning experience (9). Rogers (10) introduced the concept of experiential learning, where students actively participate in the process and take greater ownership of their learning (11). It allows learners to learn by 'doing, reflecting and thinking, and applying' (12). Experiential learning empowers students by giving them authority and accountability over their own learning while actively engaging them within the educational environment. It also fosters adaptability, promotes the use of diverse learning strategies throughout the learning cycle, and enhances both practical skills, and metacognitive abilities (13). Educators employ different strategies to increase student engagement and understanding. One of these is gamification, which incorporates game elements into an educational environment and has been reported to have a positive impact on learners (14).

Due to the COVID-19 pandemic, educational institutions have shifted from the traditional model of learning to online teaching and learning activities by early 2020 (15). Since then, many institutions of higher education have restructured their teaching and assessment methods (16). Online learning offers many benefits. This mode of learning has been found to be at least as effective as in-class delivery (17). It also provides educators in higher institutions with flexibility and reduces stress during unexpected events that require time off. Therefore, online learning could offer a major advantage for higher education in the long run (18).

This study presents the design, implementation and preliminary evaluation of an experiential online module on genetics and genomics for undergraduate students, namely, the YOUnique: From Genes to Gen (Genomics) module. Our findings offer a novel educational model that improves the conceptual understanding of genetics among diverse learners. It also enhances empathy towards individuals with genetic disorders and stimulates ethical discourse on emerging genomic technologies. The module's strength lies in its integration of personalised experiential learning with reflective dialogue, offering a scalable, inclusive model for genomics education in the digital era. It is also aligned with the growing importance of genetics and genomics in making informed health choices.

METHODS

Participants

This is a cross-sectional descriptive study. The YOUnique Genomics module was conducted during the Live Inclusive Fulfilling Experience (LIFE) Programme, a two-week summer programme offered by Universiti Sains Malaysia (USM), which aimed to reenvision learning and empower students with the perspectives and skill sets needed to thrive in the world. This programme, held from 20th September 2021 to 2nd October 2021 via an online platform, involved 282 undergraduate USM students from science and non-science courses, as well as facilitators (USM lecturers), industry, government, and non-profit organisation partners. Student enrolment was voluntary. The students' demographic data (gender, ethnicity and year of study) were collected and are summarised in Figure 1. Apart from local Malaysian students, international students also participated in the programme.

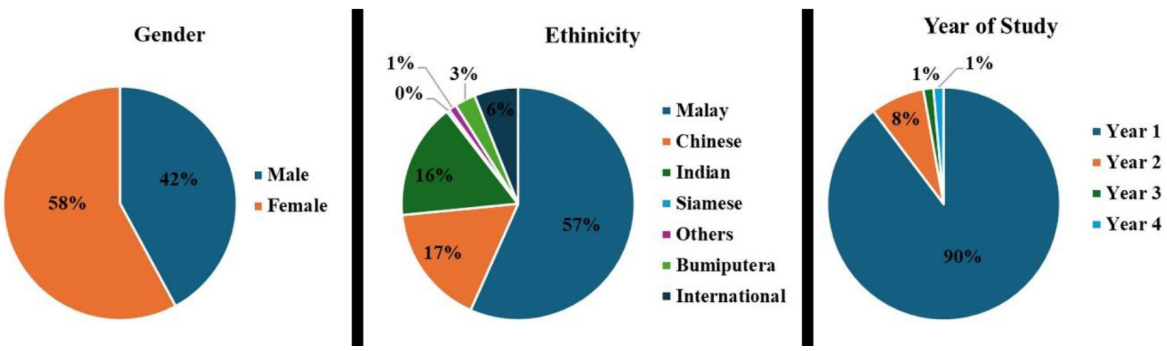

Figure 1: Demographic of the students enrolled in the USM LIFE programme.

Materials

Taking the experiential learning approach, each student was provided with a 'Box of Experience' containing A4 paper, pens and pencils, a packet of plain-flavoured biscuits and a packet of Marmite. Each facilitator received a content briefing from the module coordinator before the programme began.

Module Design and Delivery

The online learning module YOUnique Genomics was developed by lecturers at the Human Genome Centre, School of Medical Sciences, USM, to introduce fundamental concepts of genetics and genomics to undergraduate students from diverse academic backgrounds. The module was structured into four interactive sessions (Sessions I–IV) and conducted virtually using Cisco Webex with breakout rooms. A combination of videos, guided discussions, group

activities, reflective exercises and a guest webinar was employed to encourage active, and experiential learning. Each session was co-facilitated by trained facilitators, who were USM lecturers, in small groups of 8 to 10 students to ensure optimal engagement and personalised support.

Session I: Understanding your DNA

This introductory session aimed to familiarise the students with core genetic concepts and to encourage personal connections with the subject matter. The session began with a 10-minute icebreaker using guided questions and a brief slide presentation prompting reflections on inherited traits and environmental influences on genetics. Then, the students were assigned to breakout rooms. A short video titled 'Identifying Your DNA' was then presented, followed by a discussion on DNA structure and heredity, led by the facilitators. The session concluded with a 30-minute hands-on activity called 'Blood is Thicker Than Water', in which the students constructed their family pedigrees after viewing an instructional video. The group discussion focused on inheritance patterns and blood type genetics, reinforcing the students' understanding of Mendelian principles through visual aids and peer sharing.

Session II: Genotype, phenotype and the environment

This session explored the interaction between genes and the environment in shaping human traits (phenotype). The students participated in a sensory-based activity, 'Genetically Gifted—Taste and Traits', which included a Marmite taste test, physical trait analysis and a survey on taste preferences. These activities highlighted the genetic basis of both observable and sensory traits and facilitated discussions on inherited versus acquired characteristics. A video titled 'Environment, Lifestyle, Genome' introduced concepts such as ageing, mutation and epigenetics. This was followed by a reflective discussion using visual stimuli to compare lifestyle effects and genetic predispositions. The students evaluated changes in appearance due to ageing and the impact of DNA mutations through case discussions involving genetic conditions and disorders, such as Down syndrome, albinism and Prader–Willi syndrome.

Session III: Ethics and the future of genetics

The third session addressed the ethical dimensions of genetic technologies. The students viewed a video titled 'Boundaries in Genetics', which served as the basis for a case-based activity, 'What Would You Do?' This activity involved a scenario on designer babies. Discussions were guided by keywords, such as gene editing, sex selection and assisted reproduction, focusing on ethical, cultural and religious considerations. Reflection questions encouraged the students to critically assess the moral implications of genetic interventions. The session ended with an anonymous Google Forms reflection to encourage personal evaluation of the learning experience.

Session IV: The future of genomics-precision medicine

The final session emphasised the real-world application of genomics in healthcare. The students viewed a 10-minute video on precision medicine, followed by a guest webinar by a genomics industry professional discussing the diagnostic and therapeutic applications of genomics. The session concluded with a group reflection, a summary of learning points using Mentimeter, and a gamified engagement activity with a random-name-draw tool.

Module Assessment and Evaluation

The module was designed to promote self-directed and collaborative learning rather than formal assessment. Student engagement and learning were evaluated through peer sharing, group presentations and non-graded reflective surveys administered via Google Forms. QR codes were shared with students after each session to collect Experience Points (XP), a programme developed to measure competencies through experiences gained during the USM LIFE Programme. The XP app for gamified assessment, accessible at https://xplife.usm.my/, was intended to encourage student interaction and participation. Participation incentives, such as small prizes, were given to enhance motivation and engagement. Student feedback on the module was collected at the end of the programme using Google Forms.

RESULTS

The students' feedback reflected a highly positive reception of the module (Figure 2). The majority of students strongly agreed that the module was useful (72.5%) and well organised (68.6%), with the content appropriately tailored to their level (72.5%). The module activities were also well received, with 96.1% of the students describing them as fun. Trainers were especially praised, with most respondents strongly recognising their knowledge (74.5%) and finding them engaging (78.4). The online session conducted using the 'Box of Experience' was considered effective by 96.1% of the participants. Moreover, 96% of participants agreed that the overall module duration was sufficient, and 98.1% felt that the time allocated for the module tasks was adequate. Most notably, 98.1% of the students believed that the knowledge they gained from the module was applicable in their lives.

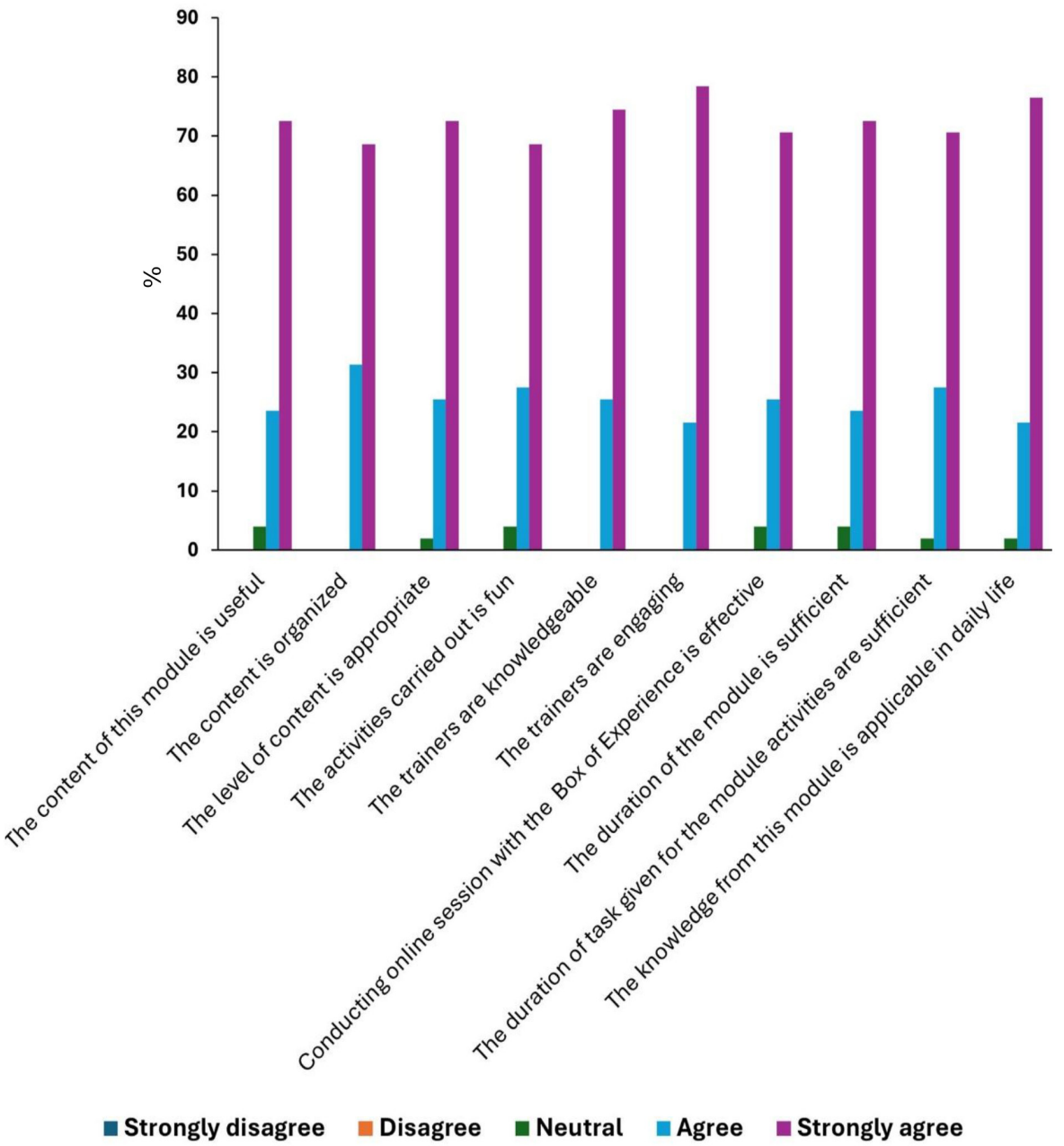

Figure 2: Student feedback on the module.

A large proportion of students (77.5%) strongly agreed that exposure to topics beyond their main fields of study was valuable. However, several factors hindered their full participation, including an unstable internet connection (39.8%), family obligations during the programme (17.3%) and part-time work commitments (12.2%). Despite these challenges, most of the students agreed that the module was beneficial and helped enhance their understanding of genetics and genomics.

Learners' understanding of genetics and genomics was explored using an interactive tool, and their responses were summarised in the Mentimeter word cloud, as shown in Figure 3. This also allowed educators to identify the diversity of responses and conceptual associations

regarding module topics. The students' responses commonly highlighted core concepts, such as DNA, genes, inheritance and health, indicating a solid foundational understanding. They also included terms related to advanced genomic technologies (e.g. CRISPR), ethical themes and pop culture references, reflecting both awareness of real-world applications and diverse engagement levels across the cohort.

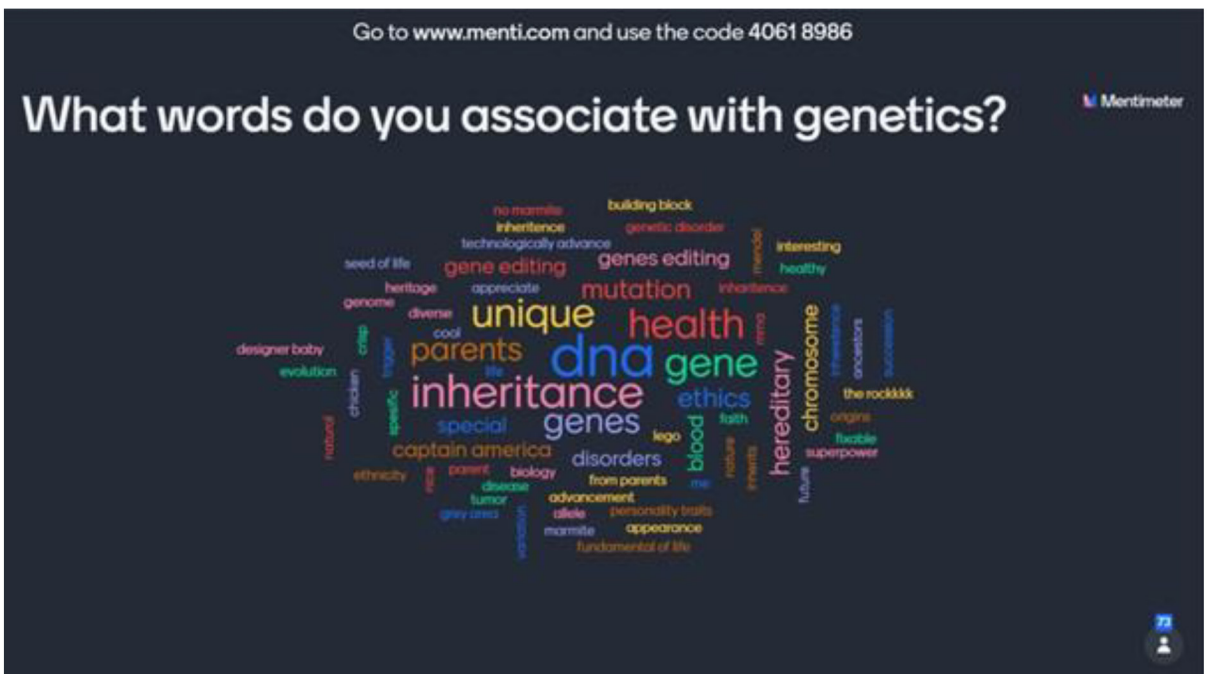

Figure 3: Student reflection about genetics at the end of the module.

The students' participation in the module was also recorded using XP. Figure 4 shows a cumulative XP score of 70 (26.4%) for the YOUnique Genomics module, compared with other modules offered during the USM LIFE Programme. This digitalised system enables easy tabulation and can be adapted for future programmes.

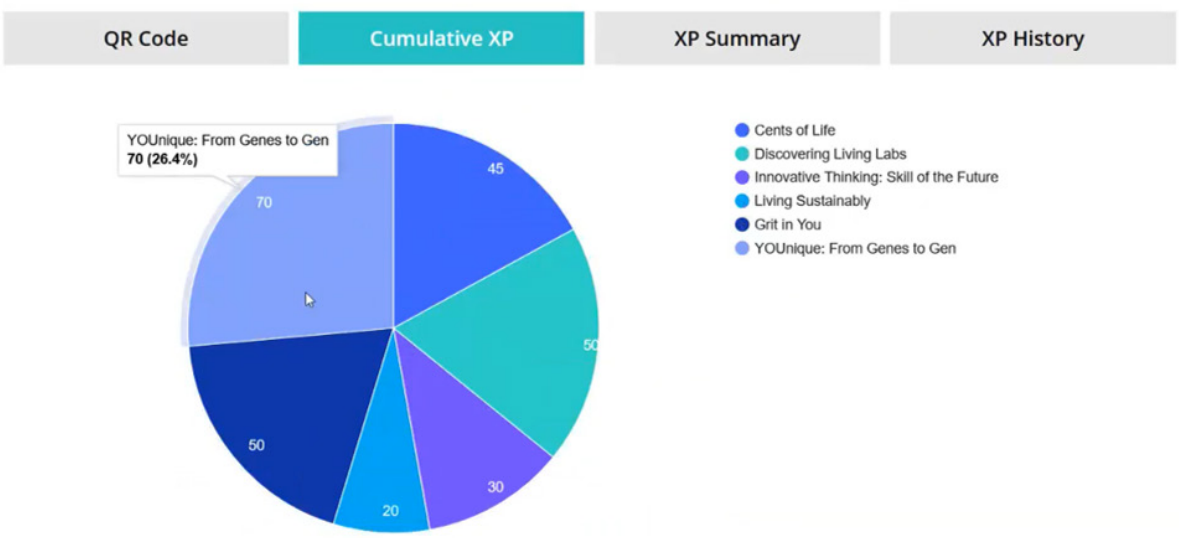

Figure 4: XP of YOUnique Genomics module.

DISCUSSION

The exponential integration of genetic knowledge in public health, diagnostics and therapeutics warrants a broader, interdisciplinary understanding of these topics across various domains of study. As life sciences evolve rapidly, the demand for graduates who are genetically and genomically literate, including those from non-biological backgrounds, is growing. However, teaching genetics and genomics, which may be complex and abstract subjects to many multidisciplinary students, poses unique pedagogical challenges (19–21).

Teaching genomics to students has been reported to help improve public perceptions and understanding (22). However, educating the public about genetics and genomics proved challenging due to various factors, including media misrepresentation and limitations in the education infrastructure (23). Specifically, there has been confusion about basic terminology, such as genes and chromosomes, alleles and allelic variation, and meiosis and mitosis, as well as misconceptions and poor application of genetic concepts, such as the influence of DNA on cell function (24). Previous reports showed a poor understanding among students of the importance of genetic information, with the majority able to describe only the nature and function of visible traits (25, 26). Understanding the complex concepts in genetics and genomics can be challenging for students from non-science backgrounds without prior knowledge of the subjects. This warrants a more strategic learning approach, such as experiential learning, which was implemented in the present module.

In many Asian countries, education and training in genetics and genomics are at varying stages of development, with clear disparities in genomic literacy between developed and developing nations (27). A collective effort to raise awareness and enhance genomic competencies in higher education is essential to fostering a more robust and equitable genomics ecosystem across the Asian region.

It is worth noting that genomics modules are often tailored to specialised subgroups or specialities with prior training in the field (28, 29), making them unsuitable for undergraduate students from diverse majors. Genomics as a field also focuses on integrated technologies and specialities (30, 31), in which a multidisciplinary approach is found to be highly effective and efficient in advancing personalised medicine (32). This highlights the need for meaningful participation in subjects from non-biology courses, such as computer science, artificial intelligence, law and engineering, to provide a comprehensive genomic initiative.

In response to educational gaps and evolving COVID-19 health advisories at the time of this programme's implementation, YOUnique Genomics was developed as an interactive online learning module to introduce the core principles of genetics and genomics to multidisciplinary undergraduate students. By incorporating gamified assessments, facilitator-led discussions and real-life case studies, the module encourages learners to explore the relevance of genetics and genomics in both scientific and societal contexts. The students' positive feedback on the module highlights the effectiveness of integrating experiential learning and digital technologies in creating inclusive educational environments that cater to diverse academic backgrounds.

The active involvement of learners in constructing family pedigrees, participating in taste tests and debating ethical issues around gene editing was particularly effective in bridging abstract genetic concepts with real-life scenarios. These activities not only enhanced comprehension but also stimulated critical thinking, ethical reasoning and an appreciation

of human genetic diversity. Understanding the social and quantitative intricacies of human genetic variation studies can equip students to engage thoughtfully and knowledgeably in a society where genetics is often misused to justify sociopolitical arguments (33).

Unlike traditional lecture-based approaches, the module's interactive multimedia content and small-group discussions encouraged deep learning and peer-to-peer knowledge exchange. This aligns with the findings of Boedeker et al. (9), who found that interactive learning sessions help close achievement gaps and promote inclusivity, particularly for non-biology students, by enabling them to contribute to discussions. This module not only promoted scientific literacy but also ethical empathy through the integration of local context scenarios. Related to this, Aramudin and Susanti (34) highlighted the positive impact of integrating local context-based education in shaping students' social and emotional development. In addition, YOUnique Genomics can be further adapted to address genetic and genomic issues across various regions, suggesting its versatility.

However, several limitations warrant consideration. First, while student feedback and engagement metrics suggest positive learning outcomes, formal assessments of knowledge gain, such as pre- and post-tests, were not performed, limiting our ability to quantitatively measure conceptual improvement. Second, the voluntary nature of participation may introduce selection bias, as students who were more motivated or interested in genetics may have been overrepresented. Third, logistical constraints, such as internet connectivity and screen fatigue, were reported by a minority of the participants, reflecting broader digital divide issues that may hinder the effectiveness of online learning.

Despite these limitations, the YOUnique Genomics module offers a replicable and scalable model for integrating genetics education into multidisciplinary undergraduate curricula. Its combination of experiential learning, ethical engagement, and online delivery makes it appropriate for both local and international implementation, particularly in settings with diverse student populations or pandemic-related disruptions that require flexible, inclusive teaching approaches.

CONCLUSION

Future iterations of the YOUnique Genomics module should incorporate more rigorous evaluation tools, such as concept inventories or longitudinal follow-ups, to assess the long-term impact on student learning and attitudes. Ultimately, this module has the potential to help close the gap in genomic literacy across academic domains and to prepare all students, regardless of major, to navigate the genomic era with knowledge, empathy, and critical awareness.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support of the former Vice Chancellor of USM, Professor Dato' Ir. Dr. Faisal Rafiq Mahamd Adikan and Professor Dr. Muhamad Saiful Bahri Yusoff for their contributions to the development of the XP app, as well as Mr. Fadzhairi Abd Jabar for his valuable contribution as an invited speaker in the module.

REFERENCES

1. National Human Genome Research Institute [Internet]. Bethesda (MD): National Human Genome Research Institute; 2018 Sep 7 [cited 2025 Aug 19]. Genetics vs. genomics fact sheet. Available from: https://www.genome.gov/about-genomics/fact-sheets/Genetics-vs-Genomics

2. Williams GA, Roubal T, Panteli D, Edwards N [Internet]. Copenhagen: European Observatory on Health Systems and Policies; 2021 Jan 28 [cited 2025 Apr 20]. Regulating the unknown: a guide to regulating genomics for health policy makers (policy brief no. 38). Available from: https://eurohealthobservatory.who.int/publications/i/regulating-the-unknown-a-guide-to-regulating-genomics-for-health-policy-makers

3. Niemi MEK, Daly MJ, Ganna A. The human genetic epidemiology of COVID-19. Nat Rev Genet. 2022;23(9):533–46. https://doi.org/10.1038/s41576-022-00478-5

4. Wu KCH, He Q, Bennett AN, Li J, Chan KHK. Shared genetic mechanism between type 2 diabetes and COVID-19 using pathway-based association analysis. Front Genet. 2022;22(1)3:1063519. https://doi.org/10.3389/fgene.2022.1063519

5. Hansson MG, Bouder F, Howard HC. Genetics and risk – an exploration of conceptual approaches to genetic risk. J Risk Res. 2018;21(2):101–8. https://doi.org/10.1080/13669877.2017.1382562

6. Stern F, Kampourakis K. Teaching for genetics literacy in the post-genomic era. Stud Sci Educ. 2017;53(2):193–225. https://doi.org/10.1080/03057267.2017.1392731

7. Boerwinkel DJ, Waarlo AJ, Boersma K, Karstens W, Jochemsen H, Knippels M, et al. Reaching a consensus on the definition of genetic literacy that is required of a twenty-first-century citizen. Sci Educ. 2017;26(10):1087–114. https://doi.org/10.1007/s11191-017-9934-y

8. Chen LS, Goodson P. Barriers to adopting genomics into public health education: a mixed methods study. Genet Med. 2009;11(2):104–10. https://doi.org/10.1097/GIM.0b013e31818fa2c7

9. Boedeker P, Steffen J, Jenssen L, Hofmann A, Meyer J, Klein S, et al. Correction to: active versus passive learning in large-group sessions in medical school: a randomised crossover trial investigating effects on learning and the feeling of learning. Med Sci Educ. 2025;35(1):459–67. https://doi.org/10.1007/s40670-025-02299-7

10. Rogers CR. Freedom to learn. Columbus, OH: Charles E. Merrill; 1969.

11. Peters RS. Freedom to learn: a view of what education might become. Interchange. 1970;1(4):111–14. https://doi.org/10.1007/BF02214887

12. Butler MG, Hebl MR, Phillips KW, Apfelbaum EP, Biernat M, Toosi NR, et al. Do, reflect, think, apply: experiential education in accounting. J Account Educ. 2019;48:12–21. https://doi.org/10.1016/j.jaccedu.2019.05.001

13. Kolb A, Kolb D. Experiential learning theory as a guide for experiential educators in higher education. Experiential Learn Teach Higher Educ. 2022;1:38. https://doi.org/10.46787/elthe.v1i1.3362

14. Lemay DJ, Bazinet L, Nori D, Morsink P, Stewart L, Dubois E, et al. Transition to online learning during the COVID-19 pandemic. Comput Human Behav Rep. 2021;4:100130. https://doi.org/10.1016/j.chbr.2021.100130

15. García-Peñalvo FJ, Corell A, Abella-García V, Grande-de-Prado M. Recommendations for mandatory online assessment in higher education during the COVID-19 pandemic. In: Burgos D, Tlili A, Tabacco A, editors. Radical solutions for education in a crisis context: COVID-19 as an opportunity for global learning. Singapore: Springer Singapore; 2021. p. 85–98. https://doi.org/10.1007/978-981-15-7869-4_6

16. Smiderle R, Rigo SJ, Marques LB, Peçanha de Miranda Coelho JA, Jaques PA. The impact of gamification on students' learning, engagement and behavior based on their personality traits. Smart Learn Environ. 2020;7(1):3. https://doi.org/10.1186/s40561-019-0098-x

17. Li C, Lalani F [Internet]. Geneva: World Economic Forum. The COVID-19 pandemic has changed education forever: this is how. c2020 [cited 2025 Mar 1]. Available from: https://www.weforum.org/agenda/2020/04/coronavirus-education-global-covid19-online-digital-learning/

18. Singh J, Zolfaghari A, Sahin I, Clark S, Gilbert S, Hassan M, et al. Online, hybrid, and face-to-face learning through the eyes of faculty, students, administrators, and instructional designers: lessons learned and directions for the post-vaccine and post-pandemic/COVID-19 world. J Educ Technol Syst. 2022;50(3):301–26. https://doi.org/10.1177/00472395211063754

19. Hott AM, Huether CA, McInerney JD, Christianson C, Fowler R, Bender H, et al. Genetics content in introductory biology courses for non-science majors: theory and practice. BioScience. 2002;52(11):1024–35. https://doi.org/10.1641/0006-3568(2002)052[1024:GCIIBC]2.0.CO;2

20. Schmid RF, Borokhovski E, Bernard RM, Pickup DI, Abrami PC. A meta-analysis of online learning, blended learning, the flipped classroom and classroom instruction for pre-service and in-service teachers. Comput Educ Open. 2023;5:100142. https://doi.org/10.1016/j.caeo.2023.100142

21. Korf BR. Genetics and genomics education: the next generation. Genet Med. 2011;13(3):201–2. https://doi.org/10.1097/GIM.0b013e31820986cd

22. Donovan BM, Semmens R, Keck P, Brimhall E, Busch K, Weindling M, et al. Genomics literacy matters: supporting the development of genomics literacy through genetics education could reduce the prevalence of genetic essentialism. J Res Sci Teach. 2021;58(4):520–50. https://doi.org/10.1002/tea.21670

23. Athanasiadis G, Nielsen FC, Hansen NR, Als TD, Jorgensen TH, Børglum AD, et al. Spitting for science: Danish high school students commit to a large-scale self-reported genetic study. PLoS One. 2016;11(8):e0161822. https://doi.org/10.1371/journal.pone.0161822

24. Dressler LG, Terry SF, Merz JF, Fraser G, Juengst ET, Livolsi V, et al. Genomics education for the public: perspectives of genomic researchers and ELSI advisors. Genet Test Mol Biomarkers. 2014;18(3):131–40. https://doi.org/10.1089/gtmb.2013.0366

25. Machová M, Ehler E. Secondary school students' misconceptions in genetics: origins and solutions. J Biol Educ. 2023;57(3):633–46. https://doi.org/10.1080/00219266.2021.1933136

26. Duncan RG, Reiser BJ. Reasoning across ontologically distinct levels: students' understandings of molecular genetics. J Res Sci Teach. 2007;44(7):938–959. https://doi.org/10.1002/tea.20186

27. Cutiongco-de la Paz EMC, Abadingo ME, Maceda EBG, Padilla CD. Genetics and genomics education and training in developing countries. In: Kumar D, editor. Genomic medicine skills and competencies. Cambridge: Academic Press; 2022. p. 17–30.

28. Delanty N, O'Reilly M, Sweeney K, Doherty C, Brown G, O'Brien M, et al. Development of a genomics module within an epilepsy-specific electronic health record: toward genomic medicine in epilepsy care. Epilepsia. 2019;60(8):1670–7. https://doi.org/10.1111/epi.16278

29. McCorkell G, Shur N, Seitz A, Wattendorff A, Alam T, Rajcan-Separovic E, et al. A national education program for rapid genomics in pediatric acute care: building workforce confidence, competence, and capability. Genet Med. 2024;26(10):101224. https://doi.org/10.1016/j.gim.2024.101224

30. Gasperskaja E, Kučinskas V. The most common technologies and tools for functional genome analysis. Acta Med Litu. 2017;24(1):1–11. https://doi.org/10.6001/actamedica.v24i1.3457

31. Evans BJ, Burke W, Jarvik GP, Korngiebel DM, McClellan M, Regier DA, et al. How can law and policy advance quality in genomic analysis and interpretation for clinical care? J Law Med Ethics. 2020;48(1):44–68. https://doi.org/10.1177/1073110520916995

32. Ma Y, Wang C, Xu Y, Zhang X, Liu Y, Li Q, et al. What is the power of a genomic multidisciplinary team approach? A systematic review of implementation and sustainability. Eur J Hum Genet. 2024;32(4):381–91. https://doi.org/10.1038/s41431-024-01555-5

33. Duncan RG, Donovan BM, Metzger KJ, Lammey RG, Gonzalez J, Ratcliff M, et al. The sociopolitical in human genetics education. Science. 2024;383(6685):826–8. https://doi.org/10.1126/science.adi8227

34. Aramudin A, Susanti R. Empathy and tolerance cultivation in primary students through local context-based social science lessons. Lentera Pendidik. 2024;27(1):191–206. https://doi.org/10.24252/lp.2024v27n1i12