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Cell and gene therapy knowledge and attitude among undergraduate pharmacy students in Malaysia: A cross-sectional study

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Research Article

Keywords: cell and gene therapy, pharmacy students, knowledge, attitude, curriculum development

Posted Date: September 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10800893/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Cell and gene therapy (CGT) is an emerging area of precision medicine with increasing clinical, ethical, regulatory and educational relevance. As future healthcare professionals, pharmacy students should be prepared to understand, manage and communicate CGT-related information. However, evidence on CGT knowledge and attitudes among undergraduate pharmacy students in Malaysia remains limited.

Methods

A cross-sectional survey was conducted among undergraduate pharmacy students in Malaysia using a content-validated, self-administered questionnaire distributed via Google Forms. The questionnaire assessed demographic characteristics, objective knowledge, self-assessed knowledge, sources of learning, suggested educational approaches and attitudes toward CGT. A total of 357 responses were analysed using IBM SPSS Statistics.

Results

Respondents demonstrated a moderate level of knowledge toward CGT, with a mean knowledge score of 11.58 ± 3.06 out of 17. Most respondents showed good understanding of basic CGT concepts, but knowledge gaps were observed in Malaysia-specific product approval, clinical indications and regulatory issues. Attitudes toward CGT were generally positive, with a mean attitude score of 39.08 ± 5.40 out of 45. Knowledge and attitude scores showed a weak positive correlation (Spearman's rho = 0.184, $p < 0.001$). Academic year, race, type of institution and prior CGT education were associated with knowledge and attitude levels, while gender was not clearly associated.

Conclusion

Undergraduate pharmacy students in Malaysia demonstrated moderate knowledge but positive attitudes toward CGT. The findings highlight the need to strengthen CGT-related content in undergraduate pharmacy curricula.

Introduction

Cell and gene therapy (CGT) involves a diverse group of products that may originate from cells, tissues, or genes. These products represent one of the most significant advances in modern medicine, offering novel therapeutic strategies for diseases that were previously difficult or impossible to treat. For example, chimeric antigen receptor (CAR) T-cell therapy has demonstrated exceptional efficacy in treating blood cancers, and its advances, in combination with other therapeutic approaches, have created numerous opportunities in improving cancer treatments (Al-Haideri et al., 2022). CGT advances precision medicine by correcting or modifying disease-causing genetic abnormalities and tailoring treatment to each patient's unique molecular characteristics (Kalidasan & Theva Das, 2024). Globally, regulatory approvals and expanding clinical pipelines reflect the growing importance of CGT in healthcare systems. As of recent reports, more than one hundred cell, gene, and RNA therapies have received regulatory approval worldwide, with several thousand additional products in various stages of clinical development (Yoon et al., 2025). These therapies demonstrate potential for long-term disease modification, highlighting the need for healthcare professionals prepared to manage, monitor, and communicate CGT-related information.

Pharmacists are expected to play an essential role in the safe and effective use of CGT. For instance, Marzal-Alfaro et al. (2021) reported pharmacists play a crucial role in ensuring the safe and reliable use of CAR T-cell drugs, by assisting with medication preparation, overseeing transportation and storage, and participating in patient assessment, education, pharmacovigilance, and monitoring.

However, a major challenge in implementing CGT in Malaysia is the limited knowledge and education among healthcare professionals. International studies have reported that healthcare professionals often demonstrate insufficient knowledge of CGT despite generally positive attitudes toward these therapies, raising concerns about professional preparedness (AlRasheed et al., 2021; Wondrasek et al., 2024). In Malaysia, existing studies have mainly focused on public perceptions or general university students and have reported low awareness and moderate understanding of gene and regenerative therapies (Kalidasan & Theva Das, 2021; Mustapa et al., 2020; Ramachandren et al., 2019). However, evidence specific to undergraduate pharmacy students is lacking. As future pharmacists expected to support CGT implementation, their level of knowledge and attitudes may differ from the general population. This lack of targeted data limits curriculum development and workforce planning, highlighting the need to systematically assess pharmacy students' knowledge and attitudes toward CGT in Malaysia. Therefore, this study aimed to assess the knowledge and attitude toward CGT among undergraduate pharmacy students in Malaysia.

Specifically, this study evaluated students' level of knowledge, examined their attitudes toward CGT, explored the association between demographic and educational factors with knowledge or attitude levels, and assessed the relationship between knowledge and attitude scores.

Methods

Study design and setting

A cross-sectional study using convenience sampling was conducted between April and June 2026 among undergraduate pharmacy students from various universities in Malaysia to assess their knowledge and attitudes toward CGT. A self-administered questionnaire was developed using Google Forms, and the survey link was distributed through online platforms, including email, LinkedIn, and WhatsApp. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies (von Elm et al., 2007). The completed STROBE checklist is provided in Appendix A.

Study population & sample size

The inclusion criteria involve undergraduate pharmacy students from any of the 21 institutions offering Bachelor of Pharmacy with Honours in Malaysia who consented to the study. Exclusion criteria include incomplete questionnaires. By computing the data via Raosoft with a margin error of 5%, confidence level of 95%, and 50% response distribution, the recommended sample size of 357 respondents was used in this study (Raosoft, 2004).

Questionnaire development and validation

A closed-ended questionnaire was designed, validated, and presented in the English language based on extensive literature (AlRasheed et al., 2021; Coller, 2019; Halimi et al., 2026; Joseph et al., 2022; Youssef et al., 2026).

This questionnaire was divided into four sections with 34 items:

1. Demographic characteristics (5 items)
2. Respondents' knowledge of CGT (17 items)
3. Self-assessed knowledge and suggested approaches to educate CGT (3 items)
4. Respondents' attitude toward CGT (9 items)

This questionnaire underwent a two-stage content validation process by two academics from clinical pharmacy or pharmacogenetics backgrounds and one regulatory officer from National Pharmaceutical Regulatory Agency (NPRA). Any amendments were made based on the feedback and suggestions received before distribution to the participants.

A content validity form was developed with a four-point Likert scale and emailed to the experts. They determined whether all items referred to the relevant aspects of constructs to be measured (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = highly relevant), the importance of each item (1 = not necessary, 2 = not essential, 3 = useful but not essential, 4 = essential), and the level of clarity of each item (1 = not clear, 2 = item needs major revisions to be clear, 3 = item needs minor revisions to be clear, 4 = clear).

In the first stage, the initial questionnaire was reviewed by two subject matter experts, resulting in an S-CVI/Ave of 0.90 and S-CVI/UA of 0.80. Based on expert feedback, six items were revised to improve clarity and relevance. A CVI value of at least 0.80 was considered acceptable (Yusoff, 2019).

After revision, the amended questionnaire was sent to a third expert for further review. Following the third expert's feedback, all the items were retained with further wording refinements, and additional items were added to strengthen the regulatory, safety, ethical, and pharmacist responsibility aspects of CGT. These revisions formed the final questionnaire.

Questionnaire outcome measures and scoring system

Questionnaire outcome measures and scoring system
Respondents' knowledge of CGT was assessed using 17 objective knowledge items in Section 2 of the questionnaire. Each correct response was awarded one point, while incorrect or "I do not know" responses were scored as zero, resulting in a total knowledge score ranging from 0 to 17. Each respondent's total knowledge scores was determined and classified into 3 levels (high, moderate and low level) using Bloom's cutoff as tabulated in Table 1 (Bloom, 1968).

Attitudes toward CGT were assessed using nine items in Section 4 of the questionnaire. Responses were measured using a Likert scale score of five levels, that is, strongly agree-5, agree-4, neutral-3, disagree-2, and strongly disagree-1, resulting in a total attitude score ranging from 9 to 45. Each respondent's total attitude scores will be determined and classified into 3 levels (positive, neutral and negative attitude) using Bloom's cutoff as tabulated in Table 1 (Bloom, 1968).

Table 1
Bloom's cutoff categories for the total knowledge and attitude scores.

Item	Category	Score (%)
Knowledge (Total items = 17)	High level	14–17 (80%-100%)
	Moderate level	10–13 (60–79%)
	Low level	< 10 (< 60%)
Attitude (Total items = 9)	Positive Attitude	36–45 (80%-100%)
	Neutral Attitude	27–35 (60–79%)
	Negative Attitude	< 27 (< 60%)
(Adapting from Bloom, 1968)		

Pilot study

A pilot test was conducted among 30 conveniently selected participants, and responses were excluded from the final analysis. Internal consistency of the attitude scale was assessed using Cronbach's alpha. The value obtained was 0.728 with values of 0.70 and above indicating good internal consistency (Taber, 2018).

Statistical analysis

The data were entered and analysed using IBM Statistical Package for Social Sciences (SPSS) version 30.0. Descriptive statistics were used to summarise demographic characteristics, knowledge responses, self-assessed knowledge, sources of learning, suggested educational approaches, and attitude responses. All categorical data was presented as frequencies (n) and percentages (%) while continuous data was expressed as mean and standard deviation (SD). Chi-square tests (or Fisher-Freeman-Halton Exact Test when cell counts were < 5) were used to examine associations between categorical demographic variables and knowledge or attitude levels. The normality of total knowledge and attitude scores was assessed using the Shapiro–Wilk test. As both variables were not normally distributed ($p < 0.05$), Spearman's rank correlation coefficient (ρ) was used to examine the relationship between knowledge and attitude scores. A p-value of less than 0.05 was considered statistically significant for all analyses.

Ethical considerations

Ethics approval

for this study was obtained from the MAHSA University Human Ethics Committee (MUHEC) (Ref No: MUHEC/JANUARY/2026/EC01). Participants were required to fill out an informed consent form before answering the survey questionnaire. Moreover, they were informed that the study involves no foreseeable risks and that their participation is entirely voluntary. They have the right to withdraw from the study at any time without justification and without any consequences. All data collected were kept confidential and secure without exposing their identity.

Results

Participant demographics

A total of 357 undergraduate students participated in this study. As shown in Table 2, the majority of respondents were female (n = 260, 72.8%), while males accounted for 97 (27.2%) of the participants. Most respondents were Chinese (n = 212, 59.4%), followed by Malay (n = 114, 31.9%), Indian (n = 18, 5.0%), and respondents of other ethnicities (n = 13, 3.6%). Regarding academic year, Year 4 students constituted the largest proportion of participants (n = 132, 37.0%), followed by Year 2 (n = 79, 22.1%), Year 3 (n = 74, 20.7%), and Year 1 students (n = 72, 20.2%). Most respondents were enrolled in private universities (n = 237, 66.4%), whereas 120 (33.6%) attended public universities. In terms of prior exposure to CGT education during their undergraduate programme, 265 (74.2%) respondents reported having prior exposure, 70 (19.6%) reported no prior exposure, and 22 (6.2%) indicated that they did not know.

Table 2
Participant demographics (n = 357).

Demographic Question	Frequency (n)	Percentage (%)
D1. Gender		
Female	260	72.8%
Male	97	27.2%
D2. Race		
Chinese	212	59.4%
Malay	114	31.9%
Indian	18	5.0%
Others	13	3.6%
D3. Academic Year		
Year 1	72	20.2%
Year 2	79	22.1%
Year 3	74	20.7%
Year 4	132	37.0%
D4. Type of Institution		
Private University	237	66.4%
Public University	120	33.6%
D5. Prior exposure to cell and gene therapy education during undergraduate programme		
Yes	265	74.2%
No	70	19.6%
I do not know	22	6.2%

Knowledge of CGT

Overall, knowledge scores indicated moderate level of knowledge on CGT among undergraduate pharmacy students (mean ± standard deviation, SD = 11.58 ± 3.06). As shown in Table 3, most respondents correctly identified that gene therapy uses genes to treat or prevent diseases (n = 346, 96.9%) and that cell therapy involves introducing new cells into defective tissue to treat disease (n = 291, 81.5%). A high proportion also knew that cell therapy can be used in regenerative medicine to repair damaged tissues (n = 313, 87.7%), that CGT products require full registration approval before clinical use in Malaysia (n = 324, 90.8%), and that the National Pharmaceutical Regulatory Agency is responsible for the registration of such products in Malaysia (n = 263, 73.7%). Similarly, most respondents were aware that viral vectors are commonly used to carry modified genes into targeted cells (n = 265, 74.2%) and that modified cells may cause serious side effects (n = 265, 74.2%).

However, several knowledge gaps were observed, particularly in Malaysia-specific and advanced regulatory areas. Only 45 respondents (12.6%) correctly identified that there is currently only a single gene product approved for clinical use in Malaysia, while 264 respondents (73.9%) selected “I do not know”. Similarly, only 71 respondents (19.9%) correctly answered that the approved gene therapy product in Malaysia is indicated for paediatric patients, with 250 respondents (70.0%) indicating uncertainty. Knowledge regarding whether gene therapy is currently available only in research settings was also limited, as 173 respondents (49.0%) answered correctly, while 134 respondents (37.5%) selected “I do not know”.

Regarding ethical and safety-related knowledge, 188 respondents (52.7%) correctly recognised that unregistered CGT products may be dangerous due to a combination of unproven safety and efficacy, possible harmful contaminants or pathogens, and lack of environmental risk assessment. Additionally, 237 respondents (66.4%) correctly indicated that genetic modification should be limited to treating or preventing diseases, while 272 respondents (76.2%) understood that strict regulations are required because genetic modification may affect human identity and future generations. These findings suggest that respondents generally had stronger knowledge of basic CGT concepts and regulatory requirements, but showed uncertainty in Malaysia-specific product availability, clinical indications, and more complex safety and ethical issues.

Table 3
Information about respondents' knowledge of CGT.

Knowledge Question	Frequency (n)	Percentage (%)
K1. Gene therapy is a technique that uses genes to treat or prevent diseases. [Answer: True]		
True	346	96.9%
False	0	0%
I do not know	11	3.1%
K2. In cell therapy, new cells are introduced into defective tissue to cure the disease. [Answer: True]		
True	291	81.5%
False	12	3.4%
I do not know	54	15.1%
K3. There is only a single gene product that has been approved for clinical use in Malaysia. [Answer: True]		
True	45	12.6%
False	48	13.4%
I do not know	264	73.9%
K4. Cell and gene therapies are currently most commonly used in oncology and haematology, with expanding applications in other fields, such as genetic disorders and neurological diseases. [Answer: True]		
True	275	77%
False	5	1.4%
I do not know	77	21.6%
K5. Introduction of modified cells into an organism can generate serious side effects. [Answer: True]		
True	265	74.2%
False	20	5.6%
I do not know	72	20.2%
K6. Gene therapy is currently available in research settings only. [Answer: False]		
True	48	13.4%
False	173	49%
I do not know	134	37.5%
K7. Gene therapy can have very serious health risks such as toxicity, inflammation, and cancer. [Answer: True]		
True	254	71.1%

Knowledge Question	Frequency (n)	Percentage (%)
K1. Gene therapy is a technique that uses genes to treat or prevent diseases. [Answer: True]		
False	21	5.9%
I do not know	82	23%
K8. Currently approved gene therapy product in Malaysia include indication for paediatric patients. [Answer: True]		
True	71	19.9%
False	36	10.1%
I do not know	250	70%
K9. Viral vectors are commonly used to carry modified genes into targeted cells. [Answer: True]		
True	265	74.2%
False	16	4.5%
I do not know	76	21.3%
K10. Cell therapy can be used in regenerative medicine to repair tissues damaged by disease or injury. [Answer: True]		
True	313	87.7%
False	3	0.8%
I do not know	41	11.5%
K11. Cell and gene therapy products must obtain full registration approval before clinical use in Malaysia. [Answer: True]		
True	324	90.8%
False	6	1.7%
I do not know	27	7.6%
K12. The National Pharmaceutical Regulatory Agency (NPRA) is the agency responsible for the registration of cell and gene therapy products in Malaysia. [Answer: True]		
True	263	73.7%
False	8	2.2%
I do not know	86	24.1%
K13. How do you think gene therapy works? [Answer: By replacing a faulty gene with a healthy copy]		
By replacing a faulty gene with a healthy copy	244	68.3%
By giving medicine to activate weak genes	9	2.5%
By altering protein function without changing genetic material	58	16.2%

Knowledge Question	Frequency (n)	Percentage (%)
K1. Gene therapy is a technique that uses genes to treat or prevent diseases. [Answer: True]		
By regulating cell activity through non-genetic biochemical pathways	27	7.6%
I do not know	19	5.3%
K14. Which cells do you think are targeted by gene therapy? [Answer: Cells with mutated genes]		
Cells with mutated genes	306	85.7%
Red blood cells	9	2.5%
Muscle cells	4	1.1%
Any cells containing sugar molecules	20	5.6%
I do not know	18	5%
K15. Which of the following is a reason why unregistered cell and gene therapy products are considered dangerous? [Answer: All of the above]		
They have not been proven safe and effective through regulatory approval.	100	28%
They may contain harmful contaminants or pathogens due to lack of quality control.	34	9.5%
They do not undergo environmental risk assessments to ensure public safety.	8	2.2%
All of the above	188	52.7%
I do not know	27	7.6%
K16. Which of the following best reflects the ethical use of genetic modification? [Answer: Genetic modification should be limited to treating or preventing diseases.]		
Genetic modification is acceptable for enhancing physical traits in healthy individuals.	73	20.4%
Genetic modification should be limited to treating or preventing diseases.	237	66.4%
Genetic modification should be used to improve intelligence and behaviour.	13	3.6%
I do not know	34	9.5%
K17. Why are strict regulations required for genetic modification technologies? [Answer: Genetic modification may impact human identity and future generations.]		
Genetic modification always causes harm.	30	8.4%
Genetic modification may impact human identity and future generations.	272	76.2%
Genetic modification is no longer experimental.	4	1.1%
Genetic modification replaces all other medical treatments.	7	2%
I do not know	44	12.3%

Self-assessed knowledge

Table 4 presented the respondents' self-assessed knowledge. More than half of the respondents (n = 182, 51.0%) selected neutral when asked whether they felt well-informed about CGT. Only 94 respondents (26.3%) agreed or strongly agreed that they were well-informed, while 81 respondents (22.7%) disagreed or strongly disagreed. These findings suggest that although some respondents perceived themselves as knowledgeable, most were uncertain about their level of understanding of CGT.

Table 4
Self-assessed knowledge on CGT.

Statement	Strongly Disagree (n, %)	Disagree (n, %)	Neutral (n, %)	Agree (n, %)	Strongly agree (n, %)
Overall, I feel that I am well-informed about cell and gene therapy.	12 (3.4%)	69 (19.3%)	182 (51%)	73 (20.4%)	21 (5.9%)

Sources of learning CGT

As shown in Table 5, the largest proportion of respondents indicated that they have learned about CGT from the school (n = 306, 85.7%), followed by media (n = 128, 35.9%), journal (n = 87, 24.4%), and seminar (n = 62, 17.4%).

Table 5
Sources of learning CGT.

Statement	Frequency (n)	Percentage (%)
From where have you learned about cell and gene therapy? *		
School	306	85.7%
Seminar	62	17.4%
Media	128	35.9%
Journal	87	24.4%

**: Respondents could pick more than one answer (percentage summation ≠ 100%).*

Suggested approaches to educate CGT

Table 6 presented the suggested approaches to educate pharmacy students about CGT, the majority of respondents indicated that the best approach was during undergraduate pharmacy studies (n = 272, 76.2%). This was followed by seminars or workshops (n = 46, 12.9%), media (n = 15, 4.2%), scientific journals or online learning resources (n = 14, 3.9%), and postgraduate studies (n = 10, 2.8%).

Table 6
Suggested approaches to educate CGT.

Statement	Frequency (n)	Percentage (%)
What do you think is the best way to educate pharmacy students about cell and gene therapy?		
During undergraduate pharmacy studies	272	76.2%
During postgraduate studies	10	2.8%
Seminars or workshops	46	12.9%
Scientific journals or online learning resources	14	3.9%
Media	15	4.2%

Attitude toward CGT

Table 7 presented the respondents' attitude toward CGT. Respondents generally demonstrated positive attitudes toward CGT (mean ± standard deviation, SD = 39.08 ± 5.40). Most respondents agreed or strongly agreed that CGT is or will soon become a useful treatment strategy (n = 323, 90.5%). A large proportion also supported the use of CGT for adults with debilitating diseases (n = 307, 86.0%) and adults with severe or fatal genetic diseases (n = 300, 84.0%), provided that the therapy is proven effective. Similarly, most respondents agreed or strongly agreed that children with severe or fatal genetic diseases should be allowed to receive CGT if it is proven effective, with 299 respondents (83.7%) supporting treatment access in both related attitude items.

Despite this generally positive attitude, respondents also expressed concerns about several aspects of CGT. Most respondents agreed or strongly agreed that they were concerned about the safety, efficacy, and ethical implications of using CGT products in clinical practice (n = 290, 81.3%). Affordability was also a major concern, with 319 respondents (89.3%) agreeing or strongly agreeing that they were concerned about the affordability of CGT. In addition, 298 respondents (83.5%) expressed concern about advertisements promoting the use of unregistered CGT products. However, professional responsibility was strongly recognised, as 327 respondents (91.6%) agreed or strongly agreed that future pharmacists have the responsibility to educate patients on the use of registered CGT products.

Table 7
Information about respondent's attitude toward CGT.

Attitude Statement	Strongly Disagree (n, %)	Disagree (n, %)	Neutral (n, %)	Agree (n, %)	Strongly agree (n, %)
A1. I believe that cell and gene therapy is or will soon become a useful treatment strategy.	2 (0.6%)	4 (1.1%)	28 (7.8%)	150 (42%)	173 (48.5%)
A2. I agree that adults with debilitating diseases should be allowed to receive cell therapy if it is proven effective.	2 (0.6%)	3 (0.8%)	45 (12.6%)	147 (41.2%)	160 (44.8%)
A3. I agree that adults with debilitating diseases should be allowed to receive gene therapy if it is proven effective.	1 (0.3%)	7 (2%)	49 (13.7%)	140 (39.2%)	160 (44.8%)
A4. I agree that children with severe or fatal genetic diseases should be allowed to receive cell therapy if it is proven effective.	4 (1.1%)	5 (1.4%)	49 (13.7%)	139 (38.9%)	160 (44.8%)
A5. I agree that children with severe or fatal genetic diseases should be allowed to receive gene therapy if it is proven effective.	4 (1.1%)	3 (0.8%)	51 (14.3%)	137 (38.4%)	162 (45.4%)
A6. I am concerned about the safety, efficacy, and ethical implications of using cell and gene therapy products in clinical practice.	1 (0.3%)	5 (1.4%)	61 (17.1%)	133 (37.3%)	157 (44%)
A7. I am concerned about the affordability of cell and gene therapy.	2 (0.6%)	3 (0.8%)	33 (9.2%)	100 (28%)	219 (61.3%)
A8. I am concerned about advertisements that promote the use of unregistered cell and gene therapy products.	5 (1.4%)	7 (2%)	47 (13.2%)	86 (24.1%)	212 (59.4%)
A9. As a future pharmacist, I have the responsibility to educate patients on the use of registered cell and gene therapy products.	3 (0.8%)	3 (0.8%)	24 (6.7%)	92 (25.8%)	235 (65.8%)

Correlation between respondents' knowledge and attitude of CGT.

As shown in Table 8, there was a weak positive correlation between knowledge and attitude scores (Spearman's rho = 0.184, $p < 0.001$). This indicates that respondents with higher knowledge scores tended to have slightly higher attitude scores. However, the strength of the relationship was weak, suggesting that knowledge was only modestly related to attitude toward CGT.

Table 8
Correlation between respondents' knowledge and attitude of CGT.

Correlation		Knowledge Score	Attitude Score
Total knowledge score	Spearman's rho Correlation	1	0.184
	Sig. (2-tailed)		< 0.001
Total attitude score	Spearman's rho Correlation	0.184	1
	Sig. (2-tailed)	< 0.001	

Association between demographic variables and levels of knowledge and attitude

The associations between demographic variables and levels of knowledge and attitude toward CGT are presented in Table 9. For knowledge level, gender was not clearly associated with knowledge level (p = 0.223). Female respondents had a slightly higher proportion of high knowledge level (n = 70, 26.9%) compared with male respondents (n = 23, 23.7%). Race was associated with knowledge level (p = 0.005), with Indian respondents showing the highest proportion of high knowledge level (n = 7, 38.9%), followed by Chinese respondents (n = 61, 28.8%), Malay respondents (n = 24, 21.1%), and respondents from other races (n = 1, 7.7%). Academic year was associated with knowledge level (p < 0.001), where Year 1 students had the highest proportion of low knowledge level (n = 35, 48.6%), while Year 3 and Year 4 students showed higher proportions of high knowledge level at 36.5% and 34.1%, respectively. Type of institution was also associated with knowledge level (p = 0.044), with public university students showing a higher proportion of high knowledge level (n = 36, 30.0%) than private university students (n = 57, 24.1%). Prior exposure to CGT education during the undergraduate programme was associated with knowledge level (p < 0.001), as respondents with prior exposure had a higher proportion of high knowledge level (n = 87, 32.8%) compared with those without prior exposure (n = 5, 7.1%).

For attitude level, gender was not clearly associated with attitude level (p = 0.305). A higher proportion of female respondents had a positive attitude (n = 208, 80.0%) compared with male respondents (n = 71, 73.2%). Race was associated with attitude level (p = 0.004), with Malay respondents showing the highest proportion of positive attitude (n = 94, 82.5%), followed by Chinese respondents (n = 163, 76.9%), respondents from other races (n = 10, 76.9%), and Indian respondents (n = 12, 66.7%). Academic year was also associated with attitude level (p = 0.010), with Year 3 students showing the highest proportion of positive attitude (n = 64, 86.5%), followed by Year 4 (n = 110, 83.3%), Year 2 (n = 59, 74.7%), and Year 1 students (n = 46, 63.9%). Type of institution was associated with attitude level (p = 0.001), where public university students had a higher proportion of positive attitude (n = 106, 88.3%) compared with private university students (n = 173, 73.0%). Prior exposure to CGT education was also associated with attitude level (p = 0.012), with respondents who had prior exposure showing a higher proportion of positive attitude (n = 216, 81.5%) compared with those without prior exposure (n = 46, 65.7%).

Table 9
Association between demographic variables and levels of knowledge and attitude.

Variable	Category	Knowledge level			p-value	Attitude level			p-value
		High (n, %)	Moderate (n, %)	Low (n, %)		Positive (n, %)	Neutral (n, %)	Negative (n, %)	
Gender	Female	70 (26.9)	142 (54.6)	48 (18.5)	0.223	208 (80.0)	48 (18.5)	4 (1.5)	0.305*
	Male	23 (23.7)	48 (49.5)	26 (26.8)		71 (73.2)	24 (24.7)	2 (2.1)	
Race	Chinese	61 (28.8)	113 (53.3)	38 (17.9)	0.005*	163 (76.9)	49 (23.1)	0 (0.0)	0.004*
	Malay	24 (21.1)	67 (58.8)	23 (20.2)		94 (82.5)	15 (13.2)	5 (4.4)	
	Indian	7 (38.9)	3 (16.7)	8 (44.4)		12 (66.7)	6 (33.3)	0 (0.0)	
	Others	1 (7.7)	7 (53.8)	5 (38.5)		10 (76.9)	2 (15.4)	1 (7.7)	
Academic Year	Year 1	5 (6.9)	32 (44.4)	35 (48.6)	< 0.001	46 (63.9)	25 (34.7)	1 (1.4)	0.010*
	Year 2	16 (20.3)	46 (58.2)	17 (21.5)		59 (74.7)	18 (22.8)	2 (2.5)	
	Year 3	27 (36.5)	39 (52.7)	8 (10.8)		64 (86.5)	9 (12.2)	1 (1.4)	
	Year 4	45 (34.1)	73 (55.3)	14 (10.6)		110 (83.3)	20 (15.2)	2 (1.5)	
Type of Institution	Private university	57 (24.1)	122 (51.5)	58 (24.5)	0.044	173 (73.0)	60 (25.3)	4 (1.7)	0.001*
	Public university	36 (30.0)	68 (56.7)	16 (13.3)		106 (88.3)	12 (10.0)	2 (1.7)	
Prior exposure to cell and gene therapy education during undergraduate programme	Yes	87 (32.8)	148 (55.8)	30 (11.3)	< 0.001	216 (81.5)	44 (16.6)	5 (1.9)	0.012*
	No	5 (7.1)	32 (45.7)	33 (47.1)		46 (65.7)	24 (34.3)	0 (0.0)	
	I do not know	1 (4.5)	10 (45.5)	11 (50.0)		17 (77.3)	4 (18.2)	1 (4.5)	

**Fisher-Freeman-Halton Exact Test was used when one or more cells have an expected frequency of less than 5*

Discussion

Knowledge and attitude toward CGT

This study found that undergraduate pharmacy students had a moderate level of knowledge toward CGT, with a mean knowledge score of 11.58 ± 3.06 out of 17. Although many respondents were able to answer basic CGT concepts

correctly, such as the meaning of gene therapy and cell therapy, they showed weaker understanding in more specific areas, including Malaysia-specific product approval, clinical indications, and regulatory issues. This suggests that students may have general awareness of CGT but lack deeper and more applied knowledge. A similar pattern was reported by AlRasheed et al. (2021), where healthcare professionals showed limited knowledge but generally positive attitudes toward gene therapy. This may be because CGT is still an emerging and highly specialised area that requires understanding of molecular biology, clinical applications, safety monitoring, ethical issues, and regulation. Therefore, basic awareness alone may not be enough to prepare future pharmacists for practice.

The moderate level of knowledge observed in this study is also consistent with studies on pharmacogenomics and genomics education among pharmacy students. Wen et al. (2022) reported that incoming pharmacy students generally believed pharmacogenomics was useful and relevant to future practice, but many lacked confidence in their clinical pharmacogenomics knowledge. Similarly, a systematic review by Wondrasek et al. (2024) found that pharmacists and pharmacy students often had positive perceptions of pharmacogenomics but insufficient knowledge and confidence to apply it in practice. Although pharmacogenomics is not identical to CGT, both areas require an understanding of genetics, personalised medicine, clinical decision-making, and patient counselling. This supports the finding that pharmacy students may be receptive to advanced genetic-based therapies but still require more structured education to develop practical competence.

Despite only moderate knowledge, respondents in this study generally demonstrated positive attitudes toward CGT. Most respondents agreed or strongly agreed that CGT is or will soon become a useful treatment strategy, and many supported its use in adults and children with severe, debilitating, or fatal diseases when proven effective. This positive attitude may be explained by the perceived therapeutic potential of CGT, especially for serious diseases with limited treatment options. Delhove et al. (2020) found that public acceptability of gene therapy was generally higher when it was used for therapeutic purposes rather than enhancement. Aiyegbusi et al. (2020) also reported that patients and the public were generally supportive of cell and gene therapies, particularly when the therapies were presented as potential treatments for serious or life-limiting conditions. Therefore, the positive attitude among respondents in this study may reflect their recognition of CGT as a promising treatment approach for severe diseases.

However, the positive attitude observed in this study did not mean that respondents accepted CGT without concern. Many respondents expressed concerns about safety, efficacy, ethical implications, affordability, and advertisements promoting unregistered CGT products. These concerns are reasonable because CGT is associated with complex clinical and ethical issues, including long-term safety, adverse events, access, cost, and regulation. Previous literature has also highlighted that concerns about gene therapy often relate to safety, uncertainty, cost, and ethical acceptability. For example, AlRasheed et al. (2021) found that around half of healthcare professionals were concerned about gene therapy, while Hampson et al. (2018) discussed evidence, value, and affordability as important challenges in gene therapy adoption. Therefore, students' concerns in the present study may reflect professional caution rather than negative attitudes. This is encouraging because future pharmacists should support innovation while also recognising risks and protecting patients from unsafe or unregistered products.

A weak positive correlation was observed between knowledge and attitude scores (Spearman's rho = 0.184, $p < 0.001$), suggesting that knowledge may contribute to attitude formation but is not the only influencing factor. Other factors, such as ethical beliefs, affordability concerns, and regulatory considerations, may also shape perceptions of CGT. This finding is consistent with previous research among healthcare professionals (AlRasheed et al., 2021).

Influence of demographic and educational factors

The present study found that academic year was associated with both knowledge and attitude levels toward CGT. Year 1 students had the highest proportion of low knowledge, while Year 3 and Year 4 students showed higher proportions of high knowledge and positive attitude. This finding is expected because students in later academic years are likely to have received more exposure to pharmacology, biotechnology, therapeutics, ethics, and clinical pharmacy content. As pharmacy students progress through the pharmacy programme, they are also more likely to encounter topics related to advanced therapies and personalised medicine. This is supported by previous studies showing that academic progression and educational exposure are associated with better genetics or pharmacogenomics knowledge. For example, Olwi et al. (2016) found that academic year was associated with genetic knowledge and attitudes toward genetic testing among college students. Therefore, the association between academic year and CGT knowledge in this study may reflect the gradual accumulation of scientific and clinical learning throughout the pharmacy curriculum.

Prior CGT educational exposure was associated with higher knowledge and more positive attitudes, suggesting that education may be an important factor in improving student preparedness. A systematic review by Omran et al. (2023) found that pharmacogenomics educational interventions improved knowledge, attitudes, and confidence among healthcare professionals and health professions students, particularly when clinical cases and competency-based teaching were included. Although the review focused on pharmacogenomics, the same principle can be applied to CGT education. Thus, undergraduate exposure to CGT may play an important role in improving students' readiness for future pharmacy practice.

Type of institution was associated with knowledge and attitude levels, with public university students showing higher proportions of high knowledge and positive attitudes. This finding should be interpreted cautiously, as curriculum structure, teaching methods, clinical exposure, and institutional resources were not assessed. Differences in CGT-related educational exposure may contribute to this variation. Shi et al. (2025) reported that hospital pharmacists may support CGT and advanced therapy medicinal products through activities such as procurement, preparation, delivery, administration, monitoring, training, and multidisciplinary collaboration. Therefore, students studying in environments with greater exposure to advanced clinical or research settings may have better awareness and attitudes toward CGT.

Race was associated with knowledge and attitude levels; however, this finding should be interpreted cautiously due to smaller subgroup sizes. The association may reflect differences in educational background, access to information, or health literacy rather than race itself. Li et al. (2023) found that acceptance of gene therapy was influenced by factors such as education and health literacy, which suggests that information access and understanding may be more important than demographic identity alone. Therefore, the race association in this study should be viewed as a contextual finding that requires further investigation rather than a direct causal factor.

Gender was not associated with knowledge or attitude levels, suggesting similar perceptions among male and female students. This is consistent with previous literature showing that associations between gender and perceptions of genetic technologies, including gene therapy, vary across different populations and study settings (AlRasheed et al., 2021; Haga et al., 2013; Wang et al., 2017; Xiang et al., 2015). Therefore, pharmacy education strategies should focus more on ensuring equal access to CGT learning opportunities for all students.

Implications for pharmacy education

The findings of this study have important implications for pharmacy education. Although students generally held positive attitudes toward CGT, their knowledge was only moderate, and many were uncertain about whether they were well-informed. This suggests a gap between interest and preparedness. As CGT products become more

available in clinical practice, pharmacists may be expected to support medication safety, patient education, product handling, monitoring, and counselling. Petrich et al. (2020) described gene replacement therapy as an area requiring pharmacist understanding of therapy characteristics, handling, administration, and clinical considerations. Shi et al. (2025) also highlighted the role of hospital pharmacists in supporting the safe and appropriate use of CGT and advanced therapy medicinal products. Therefore, pharmacy students should not only learn what CGT is, but also how pharmacists contribute to its safe and responsible use.

In the present study, most respondents indicated that undergraduate pharmacy studies were the best approach to educate pharmacy students about CGT rather than being postponed until postgraduate training or professional practice. This supports early curriculum integration. CGT content could be introduced progressively, beginning with basic concepts such as genes, vectors, cell therapy, gene therapy, and regulatory principles in the early years. In later years, teaching could move toward clinical applications, patient selection, safety monitoring, ethical decision-making, affordability, and patient counselling. This staged approach would help students move from basic awareness to applied professional competence.

Teaching methods should also be active and clinically relevant. Instead of relying only on lectures, CGT education could include case-based learning, seminars, workshops, journal discussions, simulated patient counselling, and interprofessional learning with medical, nursing, and biomedical science students. Omran et al. (2023) found that educational interventions using competency domains and clinical cases improved pharmacogenomics knowledge, attitudes, and confidence. Applying a similar strategy to CGT may help pharmacy students understand not only the science behind these therapies but also their practical role in patient care. For example, students could discuss case scenarios involving CAR-T cell therapy, gene replacement therapy, unregistered stem-cell advertisements, or affordability concerns. These activities may improve students' ability to communicate benefits and risks clearly to patients.

The concerns expressed by respondents also show that CGT education should include ethical, regulatory, and access-related content. Many students were concerned about affordability and unregistered product promotion. These are important issues because CGT products may involve high costs and complex access pathways. Hampson et al. (2018) highlighted affordability and value assessment as major challenges for gene therapy in healthcare systems. In addition, unregistered CGT products have been described as a public health concern (Ikonomou et al., 2023). Therefore, pharmacy education should prepare students to identify registered products, recognise misleading claims, understand regulatory requirements, and advise patients safely. This is particularly important because pharmacists are often accessible healthcare professionals and may be approached by patients seeking advice about new or advertised therapies.

Limitations and future research

Several limitations should be considered when interpreting these findings. First, this study used a cross-sectional design, which means that data were collected at one point in time. Therefore, the associations observed cannot prove cause and effect. For example, although prior exposure to CGT education was associated with higher knowledge levels and more positive attitudes, it cannot be concluded that such exposure directly caused these outcomes. Second, the study used a self-administered questionnaire, so the responses may be affected by response bias or social desirability bias. Some participants may have overestimated or underestimated their understanding of CGT or provided responses that they perceived as more acceptable. Third, the study used convenience sampling, with most participants from private institutions (66.4%) and fewer from public institutions (33.6%). This may limit the generalisability of the findings to all undergraduate pharmacy students in Malaysia. Future studies should consider using a more balanced sampling strategy, such as stratified random sampling, to ensure proportional representation

from both public and private institutions. Fourth, although this study assessed knowledge and attitude using a questionnaire, it did not directly evaluate students' practical competence in areas such as patient counselling, clinical decision-making, or product handling.

Future research could use longitudinal designs to examine how knowledge and attitudes change as students progress through the pharmacy programme. Interventional studies could also evaluate whether CGT workshops, case-based modules, or simulation-based teaching improve students' knowledge, confidence, and counselling skills. In addition, qualitative studies may be useful to explore why students feel uncertain about CGT and what types of learning activities they find most helpful. These future studies would provide stronger evidence to guide the development of CGT-related content in undergraduate pharmacy education.

Conclusion

Overall, the findings suggest that undergraduate pharmacy students are receptive to CGT but require more structured and applied education to strengthen their knowledge and professional readiness. CGT-related content should be integrated into undergraduate pharmacy curricula, with emphasis on basic mechanisms, clinical applications, product regulation, safety monitoring, ethical considerations, affordability, and patient counselling. Active learning approaches such as case-based learning, seminars, workshops, and simulated patient counselling may further enhance students' ability to apply CGT knowledge in future practice. As CGT continues to develop, preparing pharmacy students in this area is essential to ensure that future pharmacists can contribute effectively to the safe, ethical, and responsible use of these advanced therapies.

Declarations

Declaration of generative AI use

During the preparation of this work, the authors used AI-assisted technologies to assist with grammar checking, language refinement, and improving sentence clarity. After using this tool, the authors reviewed and edited the content as needed and takes full responsibility for the content of the manuscript.

Declaration of competing interest

The authors declare that there are no conflicts of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgement

The authors would like to thank all the participants who contributed to this study. The authors also extend their appreciation to Dr. Sohail Aziz, Dr. Chua Eng Wee, and Dr. Evelyn Loh Yun Xi for their valuable contributions and expert feedback during the content validation process of the questionnaire.

Author Contributions

W. H. Wong: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft. P. K. Wong: Conceptualization, Methodology, Supervision, Writing – review & editing. Both authors contributed to the interpretation of the results and approved the final version of the manuscript.

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