The Knowledge, Awareness and Practice on Molecular Biology among Universiti Teknologi MARA (UiTM) Students Across Peninsular Malaysia.

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ABSTRACT

This study aimed to assess the knowledge, awareness, and practice (KAP) of molecular biology among 154 undergraduate students from various Universiti Teknologi MARA (UiTM) campuses in Malaysia. A crosssectional survey design was employed using a structured questionnaire, and data were analysed using descriptive statistics, one-way ANOVA, and Pearson's correlation. Results showed that 52.60% of respondents achieved excellent knowledge, 38.31% had good knowledge, 7.14% were adequate, and 1.95% were poor ($F (3,150) = 3.92$, $p = 0.00995$). Awareness levels were higher, with 60.39% of respondents classified as excellent and 35.71% as good ($F (3,150) = 3.26$, $p = 0.023$). However, practice scores were lower, with 66.23% in the adequate category, 21.43% as poor, and only 12.34% as good ($F (3,150) = 10.00$, $p < 0.00001$). Pearson's correlation revealed a strong positive relationship between knowledge and awareness ($r = 0.76$, $p < 0.001$), a moderate positive correlation between knowledge and practice ($r = 0.42$, $p < 0.01$), and a weak, non-significant correlation between awareness and practice ($r = 0.21$, $p > 0.05$). These findings indicate that while theoretical understanding and awareness of molecular biology are relatively strong, practical engagement remains limited. Bridging this gap requires greater emphasis on hands-on learning and integration of laboratory-based modules within the curriculum. The outcomes of this study provide valuable insights for curriculum enhancement, aiming to align theoretical knowledge, awareness, and practical competency in molecular biology education.

Keywords: molecular biology, knowledge, awareness, practice, undergraduate students, UiTM

INTRODUCTION

Molecular biology is a crucial branch of modern biology. It plays an important role in understanding the architecture, functions, and internal controls within individual cells, all of which can be utilized to efficiently develop novel medications, diagnose diseases, and enhance our understanding of cell physiology (Jayarama Reddy, 2023). Therefore, it is important for the government to produce students with a strong molecular biology background, as molecular techniques and knowledge are vital for developing countries and can be applied in many sectors, including medical diagnostics, biotechnology, agriculture, the food industry, forensic science, and species identification.

Molecular biology has widespread applications across various sectors, contributing to advancements in healthcare, biotechnology, agriculture, environmental science, forensics, and pharmaceuticals. In healthcare and medicine, molecular techniques such as polymerase chain reaction (PCR), quantitative PCR (qPCR), and nextgeneration sequencing (NGS) play a crucial role in disease diagnostics, while gene therapy and vaccine development have revolutionized therapeutics (Mullis & Faloona, 1987; Shendure et al., 2017). In biotechnology, genetic engineering has enabled the development of genetically modified organisms (GMOs) for agricultural and food science applications, improving crop yield and enhancing animal breeding programs (Abdul-Aziz et al., 2022).

Molecular biology also plays a role in environmental science, where bioremediation utilizes engineered microbes to clean up pollutants, and conservation genetics helps monitor biodiversity and protect endangered species (Supple & Shapiro, 2018). These applications demonstrate how molecular biology continues to drive innovation and impact diverse scientific and industrial fields. As the new generation takes over various sectors, the government faces an urgent need for graduates with a strong understanding of fundamental principles and practical skills. To support this priority, producing students with a background in molecular biology is essential for realising the government's vision outlined in the National Biotechnology Policy 2.0 (NBP 2.0) (DBN 2.0), which emphasises key areas such as healthcare and well-being, the circular economy, biotechnology-driven industrialisation, and food security through agricultural biotechnology (Bioeconomy Corporation, 2022).

Universiti Teknologi MARA (UiTM) originated in 1956 as the Dewan Latihan RIDA (RIDA Training Centre) with the objective of improving the socio-economic status of rural Malays in Malaysia. Over the years, it evolved into a comprehensive higher education institution and was officially named UiTM in 1999. The university now operates one main campus in Shah Alam and 34 branch campuses, offering more than 500 programmes across diverse disciplines, including science and technology. As of early 2024, UiTM had an enrolment of approximately 180,000–200,000 students (Universiti Teknologi MARA, n.d.). UiTM provides a range of courses in molecular biology-related fields, such as Biomolecular Science, Applied Microbiology, and Applied Science.

However, studies are scarce that comprehensively evaluate the levels of molecular biology knowledge, awareness and practical skills among students at Universiti Teknologi MARA (UiTM) campuses across Peninsular Malaysia, especially with regard to their readiness to meet evolving job-market and research demands. Therefore, this Knowledge, Awareness and Practice (KAP) study of molecular biology aims to assess undergraduates from UiTM multi-campus settings and provide evidence-based insights to inform targeted interventions aimed at enhancing awareness, strengthening conceptual knowledge and improving practical competence in molecular biology (Ahmad et al., 2021).

Research conducted by the Malaysian Science and Technology Information Centre (MASTIC) has shown that public awareness of science, technology and innovation in Malaysia has been improving. However, despite wider recognition of biotechnology techniques, there remains a significant gap in molecular biology literacy among the general public. A study by Latifah Amin and colleagues (2011) found that respondents from the Klang Valley region perceived biotechnology as moderately risky and did not view humans as having the absolute right to manipulate living organisms. These findings suggest that limited understanding of biotechnology and molecular biology may hinder the full-scale development and application of new technologies in Malaysia's research and development sector.

According to Andrade et al. (2020), knowledge-attitude-practice (KAP) surveys first emerged in the 1950s within the fields of family planning and population research and have since become widely used tools for investigating health-related behaviours and practices associated with healthcare seeking. A KAP survey is designed to comprehensively assess what a target group knows (knowledge), feels (attitude), and does (practice) regarding a specific topic (Pillay, 2005). Recent methodological work has highlighted the value of KAP instruments for assessing educational and scientific literacy across different disciplines (Witriana et al., 2025; Zarei et al., 2024). Conducting a KAP study on molecular biology among Universiti Teknologi MARA (UiTM) students is therefore crucial to evaluating their understanding, awareness, and practices toward molecular techniques. This can facilitate targeted interventions to enhance awareness and improve students' competencies, ultimately nurturing well-prepared postgraduate students in this critical scientific field.

The assessment of knowledge, awareness, and practice (KAP) on molecular biology is essential for analysing individuals' understanding, perceptions, and behaviours to produce competent graduates and future researchers. This study examines molecular biology KAP among university students, explores factors influencing these aspects, and assesses correlations among KAP domains. The research employs a descriptive cross-sectional design to investigate the KAP of molecular biology among UiTM students. Data were collected through an online Google Form questionnaire from October 2024 to February 2025, designed in English to align with UiTM's language of instruction. Statistical analysis, including the Statistical Package for the Social Sciences (SPSS) and various inferential tests, was applied to assess KAP levels and identify factors influencing molecular biology awareness (Owojori, 2022; Witriana et al., 2025). KAP studies have been shown to effectively measure scientific literacy, student motivation, and behavioural engagement across diverse academic fields, highlighting their adaptability for molecular biology education. This study provides valuable insights for designing targeted educational interventions and awareness programs, contributing to the effective development of postgraduate students with a strong foundation in molecular biology.

METHOD

Study Design

The study adopted a descriptive cross-sectional design to assess the knowledge, awareness, and practice (KAP) of molecular biology among undergraduate students in science-based programmes at Universiti Teknologi MARA (UiTM) campuses across Peninsular Malaysia, including Shah Alam, Kuala Pilah (Negeri Sembilan), Tapah, Arau, Puncak Alam, Puncak Perdana, Sungai Buloh, and Jengka. As described by Setia (2016), a descriptive cross-sectional design entails collecting data from a defined population at a single point in time without manipulating variables. In this research, data were collected via an online questionnaire distributed between October 2024 and February 2025 to students enrolled in programmes related to molecular biology such as Biomolecular Science, Microbiology, Diploma in Science, and other general science courses.

Study Area

The study was conducted across multiple Universiti Teknologi MARA (UiTM) campuses throughout Peninsular Malaysia using an online questionnaire. The majority of respondents were based at the Shah Alam campus in Selangor, a region widely recognised as a "learning region" due to its high concentration of higher education institutions and strategic investment in academic infrastructure (Kobylinski & Prasad, 2018; Abdullah et al., 2022). Many students and parents choose Selangor for academic pursuits because of its developed educational ecosystem and robust public transportation systems. Thus, it is unsurprising that UiTM Shah Alam accounted for the largest proportion of respondents in this study.

Study Population

The study population comprised students of Universiti Teknologi MARA (UiTM) from multiple campuses across Peninsular Malaysia, representing programmes such as Biomolecular Science, Applied Microbiology, Diploma in Science, and other science-related fields. Defining the study population clearly is crucial in research design to ensure valid inferences (Michael, 2023). In 2020, Malaysia's 20 public universities recorded a total enrolment of 584,576 students, of which UiTM registered the highest enrolment at 188,701 (approximately 32.28%) (Cheam, 2021). Therefore, UiTM was selected as the most appropriate institution for this research due to its large and diverse student population distributed across multiple science-based programmes.

METHODOLOGY

As a cross-sectional study, both exposure and outcomes were measured simultaneously (Setia, 2016). Participants were selected based on inclusion and exclusion criteria. The inclusion criteria were full-time UiTM undergraduate students pursuing science-based programmes, particularly those related to molecular biology. The exclusion criteria were full-time UiTM undergraduate students enrolled in non-science programmes and postgraduate students.

This design was chosen for its efficiency, cost-effectiveness, and ability to determine associations between KAP levels related to molecular biology among UiTM students in Peninsular Malaysia.

Sample Size

A sample is a subset of individuals selected from a population that represents the characteristics of that population. The sample in this study comprised 154 UiTM students. The sample size was determined based on a quantitative design to ensure sufficient statistical power for analysis.

To achieve a medium effect size ($f = 0.25$) at a significance level ($\alpha = 0.05$) with 10 degrees of freedom, a sample size of 25 respondents per group was required to obtain a power of 0.80 (Amin et al., 2011). Therefore, a minimum of 25 respondents was assigned to each group, with additional participants included to account for incomplete responses or larger population sizes.

Sampling Method

This study employed a convenience sampling method, a type of non-probability sampling that collects data from individuals who are readily available and willing to participate (Sulaiman et al., 2015). According to Shantikumar and Barratt (2018), this method allows generalization from a subset of a population without surveying every individual, making it time- and cost-efficient.

In this study, respondents were recruited from UiTM campuses across Peninsular Malaysia using online distribution channels. Although convenience sampling may limit generalizability, clear inclusion and exclusion criteria were established to ensure data relevance and consistency (Nikolopoulou, 2022; David, 2017).

Inclusion and Exclusion Criteria

Inclusion Criteria: Full-time UiTM undergraduate students pursuing science-related programmes, particularly those involving molecular biology.

Exclusion Criteria: Full-time UiTM undergraduate students from non-science programmes and postgraduate students.

Data Collection

Data collection was conducted between October 2024 and February 2025 using an online Google Form questionnaire. The questionnaire was distributed to students who volunteered to participate and met the inclusion criteria. It was prepared in English to align with UiTM's medium of instruction.

Online Consent Form

Prior to participation, students received a brief explanation of the study and provided informed consent electronically before accessing the questionnaire. Clicking "Next" on the form indicated consent to participate. Participation was voluntary, and respondents could withdraw at any point without penalty.

Questionnaire Design

The questionnaire was adapted from previous studies (Amin et al., 2011) and reviewed by an expert in molecular biology education for content validity. It comprised four sections:

Part A: Socio-demographic data

Part B: Knowledge

Part C: Awareness

Part D: Practice

Part A collected demographic information such as gender, academic programme, educational background, semester, age, and university branch.

Part B assessed molecular biology knowledge through ten statements covering basic theory, definitions, and functions.

Part C measured awareness regarding molecular biology applications through ten statements rated on a fivepoint Likert scale: Strongly Agree, Agree, Not Sure, Disagree, and Strongly Disagree.

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Part D evaluated respondents' laboratory-related practice and hands-on experiences in molecular biology, using the same Likert scale.

Data Analysis

Data analysis involves refining, transforming, and modelling data to extract meaningful insights (Johnson, 2019).

In this study, data were analysed using the Statistical Package for the Social Sciences (SPSS) Version 30.0 (Rahman & Golam, 2021). Descriptive statistics such as frequency, percentage, mean, and standard deviation were employed to summarise respondents' Knowledge, Awareness, and Practice (KAP) levels.

Before conducting inferential analyses, data screening and cleaning were performed to ensure accuracy and completeness. Normality of data distribution was assessed using the Shapiro–Wilk test and visual inspection of histograms. Reliability was evaluated using Cronbach's alpha to determine the internal consistency of questionnaire items. A Cronbach's alpha coefficient of ≥ 0.6 was considered acceptable for exploratory research (Setia, 2016).

Inferential Analysis

Inferential analyses were employed to determine significant relationships and group differences within the dataset. A one-way Analysis of Variance (ANOVA) was conducted to examine whether Knowledge, Awareness, and Practice (KAP) scores differed significantly among campus groups. When the ANOVA revealed statistically significant results, Tukey's Honestly Significant Difference (HSD) post hoc test was performed to identify specific group-to-group differences while controlling for familywise Type I error rates (Field, 2013).

Additionally, correlation analysis was conducted using Pearson's correlation coefficient (r) to assess the strength and direction of linear relationships between knowledge, awareness, and practice scores. Correlation values were interpreted following Turney (2023), where values closer to ±1 indicate stronger relationships, and a significance level of $p < 0.05$ was adopted for all statistical tests.

Scoring System

Each response in the KAP questionnaire was assigned a numerical score as shown in Table 1. The total score for each respondent was obtained by summing all responses in each section. The interpretation of KAP levels followed Bloom's cut-off points (Nahida, 2007), as presented in Table 2.

Table 1. Scoring system for each response of KAP on molecular biology questionnaire.

Response	**Score**				
	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Knowledge	4	3	2	1	0
Awareness	4	3	2	1	0
Practice	4	3	2	1	0

Table 2. Scoring system for the level of KAP on molecular biology questionnaire.

Percentage of total score (%)	**Total score of knowledge**	**otal score of Awareness**	**Total score of Practice**	**Level**
80-100	30-40	30-40	30-40	Excellent

60-79	20-29	20-29	20-29	Good
40-59	10-19	10-19	10-19	Adequate
0-39	0-9	0-9	0-9	Poor

Ethics

Consent was obtained from all participants and institutions involved in the study before any personal information was collected. The confidentiality of all participants was strictly maintained, and the names of individuals and institutions involved in the questionnaires and interviews were kept anonymous.

RESULT AND DISCUSSION

Respondent's Socio-Demographic

In this study, there are total of 154 respondents obtained from the main campus UiTM Shah Alam, Selangor (UiTMSA), and across multiple branches of UiTM including UiTM Cawangan Kuala Pilah, Negeri Sembilan (UiTMKP), UiTM Tapah (UiTMT), UiTM Arau (UiTMA), UiTM Puncak Alam (UiTMPA), UiTM Sungai Buloh (UiTMSG), UiTM Jengka (UiTMJ) and UiTM Puncak Perdana (UiTMPP). The respondents were divided into four main groups namely group A (UiTMSA, n= 70) group B (UiTMKP, n= 34), group C (UiTMA & UiTMT, n= 25) and group D (UiTMJ, UiTMPP, UiTMSG, and UiTMPA, n= 25). The distribution of groups is primarily due to the similarity in courses and educational levels among respondents from different UiTM campuses, with the majority coming from science programs. For instance, UiTMA and UiTMT have all respondents from applied science or diploma in science backgrounds where it can be in the same groups which is group C meanwhile group D is created because of the differences in science courses that is not entirely related to molecular biology. In addition, group A is created due to the majority of respondents that are studying the subject of molecular biology and enrolled in the bachelor's degree in Biomolecular Science, Applied Microbiology and science related to molecular biology meanwhile group B is created because of all the respondents are enrolling in the diploma in microbiology. The Table 3 below shows the distributions of respondents according to their respective groups.

Table 3. Distribution of respondents according to campus group, institution, and programme background.

Group	n	Name of Instituitions	Abbreviations	Location	Description of respondents
A	70	UiTM Shah Alam	UiTMSA	Selangor	Students pursuing studies in molecular biology or related sciences.
B	34	UiTM Cawangan Kuala Pilah	UiTMKP	Negeri Sembilan	Students enrolling in Diploma of Microbiology with exposure to molecular biology subjects.
C	18	UiTM Tapah UiTM Arau	UiTMT UiTMA	Perak Perlis	Students enrolling in Diploma in Science with exposure in biology subjects.
D	25	Other UiTM Campuses	UiTMJ UiTMPP UiTMSG UiTMPA	Selangor & Pulau Pinang	Students from various disciplines including business, accounting, health sciences, engineering and information technology (IT).

Respondent's Gender and Age

Out of 154 respondents, the majority were female (72.73%, n = 112), while male respondents accounted for 27.27% (n = 42) (Table 4). This gender distribution reflects the higher male enrolment trend in certain sciencerelated programmes within the sampled campuses. This disparity is primarily because the student's intake at UiTM has a predominantly female student population. Consequently, the sample for this study naturally reflected this demographic distribution, resulting in a much lower number of male participants. Gender might play a part in the vital differences in students' academic performance. The majority of research indicates that women outperform their male counterparts (Farooq, Chandhry, & Shafiq, 2011). Another reason is that men have been quite at ease in a patriarchal culture, whereas women have been compelled to overachieve in order to establish themselves (Alyousif & Sallehuddin, 2024).

In terms of age, most respondents were between 18–20 years old (53.25%, n = 82), followed by those aged 21–23 years (37.66%, n = 58), and a smaller proportion aged 24 years and above (9.09%, n = 14). The mean age was 20.63 ± 1.87 years. This distribution indicates that most participants were in their early twenties, which aligns with the typical age range of university students enrolled in the degree and diploma courses in UiTM and in the world generally (Salleh et al., 2024).

Table 4. Distribution of respondents by gender and age (n = 154).

Variable	Category	n	%
Gender	Female	112	72.73%
	Male	42	27.27%
Age	18–20 years	82	53.25%
	21–23 years	58	37.66%
	≥ 24 years	14	9.09%

Respondent's Academic Background

Most respondents were enrolled in bachelor's degree programmes (55.84%, n = 86), followed by Diploma (42.86%, n = 66) and a small proportion in Postgraduate programmes (1.30%, n = 2) (Table 5). A degree can led to specialized careers and leadership positions where the salary is also higher than diploma (University of Nottingham, 2024). However, second highest respondents were in diploma programmes, likely due to the large intake of students who continued their studies directly after secondary school. This trend may be attributed to the fact that diploma programmes are generally shorter in duration and provide a faster pathway to employment (Oswald-Egg & Renold, 2021).

In terms of faculty affiliation, the majority came from the Faculty of Applied Sciences (76.62%, n = 118), with smaller groups from the Faculty of Health Sciences (9.09%, n = 14) and other faculties such as Engineering, Education, and Computer Science (14.29%, n = 22).

Semester distribution showed the largest group in Semester 5 (47.01%, n = 57), followed by Semester 6 (16.88%, n = 26) and Semester 1 (22.07%, n = 34). This is because the enrolment of the students in UiTM is increasing in 2023 reflecting higher student's numbers in semester 5 UiTM (UiTM, 2024). The remaining respondents were spread across other semesters, with very few in the final semesters (1.30%, n = 2). The average semester of the respondents was 4.22 ± 2.04, indicating that the sample comprised a mix of early-, mid-, and late-stage students, with a higher concentration in the middle semesters. This distribution ensures a deeper understanding on assessment of molecular biology knowledge, awareness, and practices across different stages of academic progression. It highlights how students' understanding and engagement with the topic evolve as they advance through their program (Southard et al., 2016).

Table 5. Distribution of respondents by academic background (n = 154).

Variable	Category	n	%
Programme Level	Diploma	66	42.86%
	Bachelor's Degree	86	55.84%
	Postgraduate	2	1.30
Faculty	Applied Sciences	118	76.62%
	Health Sciences	14	9.09%
	Others (Engineering, Education & Computer Science)	22	14.29%
Semester	Semester 1	34	22.07%
	Semester 2	4	2.60%
	Semester 3	10	6.49%
	Semester 4	9	5.84%
	Semester 5	57	47.01%
	Semester 6	26	16.88%
	Semester 7	12	7.79%
	Semester 8 & 9	2	1.30%

Knowledge, Awareness, and Practice (KAP) on Molecular Biology

Overall Distribution of KAP Levels

Table 6 summarises the distribution of respondents across the four categories—Excellent, Good, Adequate, and Poor—for Knowledge, Awareness, and Practice. Figure 1 provides a visual comparison of these proportions, while Figure 2 presents the mean scores (±SD) for each domain.

Table 6. Overall KAP distribution and mean scores

Domain	Excellent (%)	Good (%)	Adequate (%)	Poor (%)	Mean ± SD (Range)
Knowledge	52.60	38.31	7.14	1.95	28.85 ± 7.39 (0–40)
Awareness	60.39	35.71	3.90	0.00	31.72 ± 5.20 (0–40)
Practice	0.00	12.34	66.23	21.43	16.62 ± 6.58 (0–40)

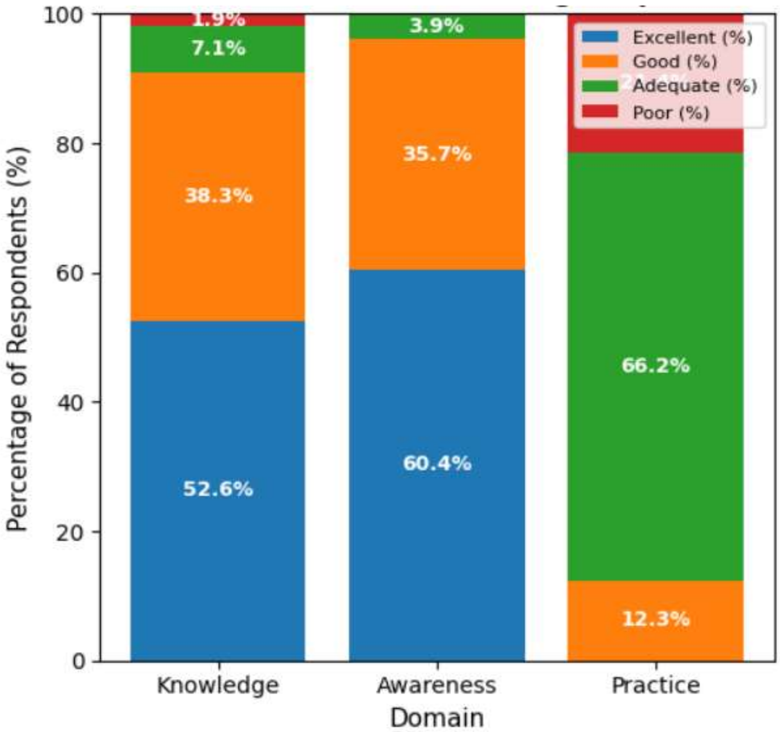

Figure 1. Proportion of respondents in each level of KAP on molecular biology.

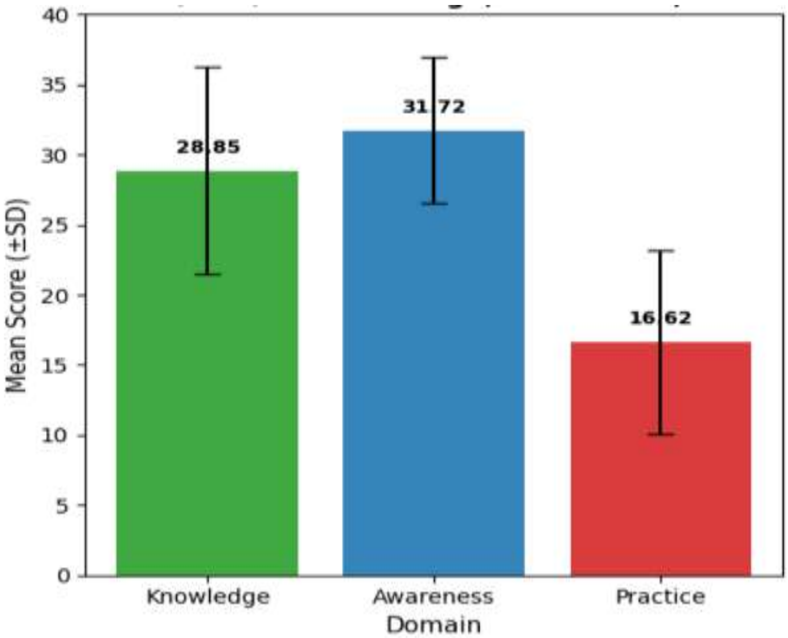

Figure 2. Mean scores (±SD) for Knowledge, Awareness, and Practice domains on molecular biology.

Knowledge of Molecular Biology

Out of 154 respondents, 52.60% achieved excellent knowledge, 38.31% had good knowledge, 7.14% were adequate, and 1.95% were poor. The overall mean knowledge score was 28.85 ± 7.39 (range: 0–40). By campus grouping, Group B (UiTM Kuala Pilah) recorded the highest mean score (32.21 ± 6.60; 100.0% good/excellent), followed by Group C (28.68 ± 5.52; 96.0% good/excellent), Group A (28.01 ± 8.70; 85.7% good/excellent), and Group D (25.84 ± 6.35; 88.0% good/excellent) (Table 7; Figure 3).

One-way ANOVA confirmed a statistically significant difference in knowledge scores among groups ($F(3,150) = 3.92$, $p = 0.00995$). Post-hoc Tukey's HSD revealed that Group B scored significantly higher than both Group

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A (p = 0.0398) and Group D (p = 0.0080), while other pairwise comparisons were not significant. This finding shows Group B were well versed in molecular biology knowledge, primary function of DNA and RNA's role in protein synthesis.

These findings highlight that respondents from Group B demonstrated a stronger factual understanding of molecular biology concepts compared to other campuses, although the variation among groups was less pronounced than in practice scores. This finding aligns with recent work showing enhanced molecular biology content knowledge when students engage in blended hands-on/virtual lab models (Haberbosch et al., 2025). Furthermore, advanced biology students' conceptions of scientific models have been shown to influence their understanding, skills and attitudes in molecular biology (Waring-Sparks, 2024). High competency in molecular laboratory knowledge among Group B students was also reported by Azmir et al. (2024).

Table 7. Knowledge level and mean score on molecular biology by campus group (n = 154).

Campus Group	Excellent n (%)	Good n (%)	Adequate n (%)	Poor n (%)	Mean ± SD
Group A (UiTMSA)	8 (11.4%)	52 (74.3%)	8 (11.4%)	2 (2.9%)	28.01 ± 8.70
Group B (UiTMKP)	6 (17.6%)	28 (82.4%)	0 (0.0%)	0 (0.0%)	32.21 ± 6.60
Group C (UiTMa&UiTMT)	2 (8.0%)	22 (88.0%)	1 (4.0%)	0 (0.0%)	28.68 ± 5.52
Group D (UiTMJ, UiTMPP, UiTMSG, UiTMPA)	1 (4.0%)	19 (76.0%)	4 (16.0%)	1 (4.0%)	25.84 ± 6.35

Figure 3. Mean knowledge scores on molecular biology by campus group with standard deviation (SD) error bars. Group B (UiTM Kuala Pilah) achieved the highest mean score, while Group D had the lowest.

Awareness of Molecular Biology

In terms of awareness, 60.39% of respondents achieved *excellent* awareness, 35.71% had *good* awareness, and only 3.90% were in the *adequate* category, with none in *poor*. The overall mean awareness score was 31.72 ± 5.20 (range: 0–40) indicating that most respondents were highly aware of molecular biology applications, ethical considerations, and its relevance in biotechnology and related fields.

By campus grouping, Group B once again ranked highest (34.62 ± 4.58; 100.0% good/excellent), followed by Group C (33.40 ± 3.48; 96.0% good/excellent), Group D (32.12 ± 4.68; 96.0% good/excellent), and Group A (33.26 ± 4.54; 91.43% good/excellent) (Table 8; Figure 4).

One-way ANOVA indicated a statistically significant difference in awareness scores among the groups ($F(3,150) = 3.26$, $p = 0.023$). However, post-hoc Tukey's HSD did not reveal significant pairwise differences after adjustment for multiple comparisons.

These results suggest that although awareness levels were consistently high across campuses, Group B tended to outperform slightly, while overall differences between groups were smaller compared to those observed for knowledge and practice. This may be explained by the fact that Group B primarily offers programmes under the Faculty of Applied Sciences, where most students are already familiar with molecular biology subjects as part of their curriculum (UiTM Negeri Sembilan, 2025). This finding is in line with prior research showing that students enrolled in science and biotechnology-related programmes exhibit higher awareness of molecular biology applications than their non-science counterparts (Abu-Qamar et al., 2015). Further, disciplinary background and prior exposure to lab-based concepts have been shown to influence student experiences and awareness in molecular and cell biology courses (Courtney et al., 2025)

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Table 8. Awareness level and mean score on molecular biology by campus group (n = 154).

Campus Group	Excellent n (%)	Good n (%)	Adequate n (%)	Poor n (%)	Mean ± SD
Group A (UiTMSA)	93 (60.39%)	55 (35.71%)	6 (3.90%)	0 (0.00%)	33.26 ± 4.54
Group B (UiTMKP)	30 (88.24%)	4 (11.76%)	0 (0.00%)	0 (0.00%)	34.62 ± 4.58
Group C (UiTMa&UiTMT)	18 (72.00%)	7 (28.00%)	0 (0.00%)	0 (0.00%)	33.40 ± 3.48
Group D (UiTMJ, UiTMPP, UiTMSG,UiTMPA)	12 (48.00%)	9 (36.00%)	0 (0.00%)	0 (0.00%)	32.12 ± 4.68

Figure 4. Mean awareness scores by campus group on molecular biology with standard deviation (SD) error bars. Group B (UiTM Kuala Pilah) achieved the highest mean score, while Group D had the lowest.

Practice in Molecular Biology

Out of 154 respondents, 20.13% demonstrated *excellent* practice, **48.70%* had *good* practice, **16.88%* were *adequate*, and **14.29%* were *poor*. The overall mean practice score was 16.62 ± 6.58 (range: 0–40).

When analysed by campus groups, Group B recorded the highest mean score (23.12 ± 7.11; 94.12% good/excellent), followed by Group C (21.87 ± 6.27; 84.0% good/excellent), Group A (16.44 ± 9.32; 60.0% good/excellent), and Group D (11.18 ± 8.23; 44.0% good/excellent) (Table 9; Figure 5).

A one-way ANOVA revealed a statistically significant difference in practice scores among campus groups ($F(3,150) = 10.00$, $p < 0.00001$). Post-hoc Tukey's HSD analysis further confirmed that Group B scored significantly higher than both Group A and Group D ($p < 0.01$), while Group C scored significantly higher than Group D ($p < 0.001$).

These findings indicate substantial variability in hands-on molecular biology proficiency across campuses, with Groups B and C outperforming others, while Group D lagged behind. This highlights the need for targeted practical training interventions, particularly for Group D, to bridge the gap between theoretical knowledge and laboratory practice. Lower scores in molecular biology practice among students from non-biology disciplines (e.g., business, accounting, health sciences, engineering, IT) are expected, as these programmes often emphasize theoretical or applied aspects of their respective fields rather than experimental science. Gormally & Heil (2022) highlighted that non-science majors generally experience reduced exposure to laboratory environments and limited engagement with experimental design, leading to lower confidence and performance in biology-related practical tasks. This supports the observed trend in this study, where respondents from non-biology backgrounds demonstrated weaker molecular biology practice scores due to minimal laboratory experience.

This suggests that practical skills gaps were common across all campuses, and that targeted hands-on training could be beneficial in strengthening technical competence. The low level of practical skills after the Covid-19 outbreak because they are still used to study online rather than physical (Katherine et al., 2023). Maglio et al. (2025) similarly reported that the shift to remote and hybrid laboratory instruction during the pandemic resulted in notable declines in students' wet-lab proficiency and confidence in performing experimental procedures, underscoring the long-term impact of disrupted practical training on molecular biology education. Not only that, but Malaysia also has a low high-skilled workers than other countries in Asia due to the fact that Malaysia is lacking mass of professional scientists and researchers in the country to develop innovation (Mustapha, 2017).

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Table 9. Practice level and mean score on molecular biology by campus group (n = 154).

Campus Group	Excellent n (%)	Good n (%)	Adequate n (%)	Poor n (%)	Mean ± SD
Group A (UiTMSA)	0 (0.00%)	13 (18.57%)	45 (64.29%)	12 (17.14%)	16.44 ± 9.32
Group B (UiTMKP)	0 (0.00%)	8 (23.53%)	26 (76.47%)	0 (0.00%)	23.12 ± 7.11
Group C (UiTMa&UiTMT)	0 (0.00%)	9 (36.00%)	14 (56.00%)	2 (8.00%)	21.87 ± 6.27
Group D (UiTMJ, UiTMPP, UiTMSG, UiTMPA)	0 (0.00%)	5 (20.00%)	12 (48.00%)	8 (32.00%)	11.18 ± 8.23

Figure 5. Mean practice scores by campus group on molecular biology with standard deviation (SD) error bars. Group B (UiTM Kuala Pilah) achieved the highest mean score, while Group D had the lowest.

Correlation Analysis between KAP of Molecular Biology

Table 10 shows the overall distribution of KAP levels among respondents (n = 154). Knowledge and awareness domains recorded high mean scores of 28.85 ± 7.39 and 31.72 ± 5.20, respectively, indicating that students possessed good theoretical understanding and awareness of molecular biology. However, practice recorded the lowest mean score (16.62 ± 6.58), suggesting limited hands-on experience among the respondents.

Table 10. Overall distribution of Knowledge, Awareness, and Practice (KAP) scores on molecular biology among UiTM Students (n = 154).

Domain	Mean ± SD	Score Range	Level Interpretation
Knowledge	28.85 ± 7.39	0–40	High theoretical understanding
Awareness	31.72 ± 5.20	0–40	Excellent awareness of molecular biology applications
Practice	16.62 ± 6.58	0–40	Limited hands-on experience

To further explore the relationships between these domains, a correlation analysis was conducted (Table 11). The correlation between knowledge and awareness showed a strong positive relationship ($r = +0.976$, $p < 0.001$), indicating that higher knowledge of molecular biology was strongly associated with greater awareness of its applications. In contrast, the correlation between awareness and practice was weak and non-significant ($r = +0.302$, $p > 0.001$), suggesting that increased awareness did not necessarily translate into improved laboratory practices. Meanwhile, the correlation between knowledge and practice showed a moderate positive relationship ($r = +0.582$, $p < 0.001$), indicating that students with stronger knowledge of molecular biology tended to demonstrate slightly better practical skills.

These findings highlight that while UiTM students exhibited commendable knowledge and awareness of molecular biology, their laboratory practice remained relatively low. The strong link between knowledge and awareness emphasizes that theoretical understanding contributes significantly to perception, consistent with Southard et al. (2016), who found that undergraduates with a deeper conceptual grasp of molecular mechanisms also demonstrated higher awareness and understanding of molecular processes, whereas the moderate link between knowledge and practice underscores the need for more hands-on molecular laboratory exposure. Enhancing experiential learning through workshops, laboratory sessions, or molecular technique demonstrations could help bridge this knowledge–practice gap. Qu et al. (2024) similarly reported that active and team-based molecular biology instruction improved students' confidence and laboratory proficiency, suggesting that innovative pedagogical approaches can close the theory–practice divide.

Table 11. Correlation coefficients between Knowledge, Awareness, and Practice (KAP) scores on molecular biology among UiTM students (n = 154).

Variables	**r-value**	**p-value**	**Interpretation**
Knowledge vs Awareness	+0.976	< 0.001	Strong positive correlation — greater knowledge improves awareness.
Awareness vs Practice	+0.302	> 0.001	Weak correlation — awareness has minimal impact on practice.
Knowledge vs Practice	+0.582	< 0.001	Moderate positive correlation — higher knowedge relates to better practice.

The correlation results indicate that students with greater theoretical knowledge tend to have higher awareness of molecular biology concepts and applications. However, this awareness does not necessarily lead to improved practice, possibly due to limited laboratory exposure or lack of access to molecular tools and facilities. This aligns with findings from Azmir et al., (2024), which reported that students often struggle to transfer theoretical knowledge into technical competence without consistent laboratory engagement. Similar findings were reported by Amin et al. (2011), where a weak correlation was found between knowledge and practice among molecular biology students. Therefore, while educational emphasis on theory has been effective, more experiential-based learning should be integrated into the curriculum to strengthen practical competencies.

CONCLUSION

This study explored the knowledge, awareness, and practice (KAP) of molecular biology among undergraduate students from various UiTM campuses across Peninsular Malaysia. The findings revealed that students generally possessed good theoretical understanding and awareness of molecular biology but showed limited engagement in practical applications. Differences in KAP levels were observed across campuses, reflecting variations in course structures and laboratory exposure. Students from programs with greater laboratory integration demonstrated higher competency, while those from non-biology or less lab-focused programs showed weaker performance.

Overall, the study highlights the importance of strengthening hands-on experience to complement theoretical learning. Enhancing students' exposure to molecular techniques will better equip them with practical competencies that align with the demands of scientific research and industry.

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