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Assessing the Improvement of Molecular Techniques Practical Skills Post-COVID-19 Lockdown in Undergraduate Students

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Abstract

This research investigates the use of practical training as a strategy for improving the molecular techniques laboratory skills among second-year Diploma in Microbiology students at Universiti Teknologi MARA (UiTM) Negeri Sembilan, Malaysia, after the COVID-19 pandemic lockdown. This is because during the lockdown, these students were forced to do most of their learning through the web which led to the sky issue. A face- to- face laboratory skills session offered to 30 participants on their competencies in molecular lab equipment usage, their grasp of the laboratory procedures and the application of the molecular techniques. Data were collected using a skills performance rubric and pre-and post- session questionnaires and were subjected to statistical analysis. There were excellent results, reflecting improvements in nearly all the abilities that were assessed in the students, making it clear that practical lessons are very important in the study of science. The recommendations highlight the need for both practical sessions, so that the students are better prepared for the molecular biology challenges that lie ahead.

Keywords: Molecular Techniques, Practical Skills Acquisition, COVID-19 Educational Impact, Laboratory Training, Online Learning Challenges

Introduction

Biology as a scientific field of study should be learnt partly through experimental methods. Mainstream of the course in biology cannot be considered as comprehensive without including some practical work in it (Yadav and Mishra, 2013). Furthermore, in many science-based fields such as microbiology, molecular biology and others, students are expected to demonstrate proficiencies that are traditionally evaluated face to face. Science students need to develop their biology skills that will equip them for life; enable them to solve problems and think critically. However, due to the coronavirus (COVID-19) pandemic, more than 1,300 higher education institutions cancelled in-person classes and moved to online delivery in March 2020 (The College Crisis Initiative, 2021). Furthermore, the study by Matthew et al.

(2023) found that poor digital literacy, lack of digital learning resources, poor internet connectivity, lack of opportunities for practical lessons and burden of domestic chores were barriers and main impact of the lockdown on practical learning among higher education students during COVID-19 pandemic.

During the COVID-19 pandemic, the significant increase in the use of ICT in the learning process and the focus of academics on the quality of the process have led them to take a greater interest in the concept of active student learning (Adedoyin et al., 2020). However, a key challenge for online learning is ensuring the effectiveness of converting acquired knowledge into practical skills that are applicable to real-world work (Tsai, 2020) and life situations (Herdan and Stuss, 2019). The main challenges that may hinder the development of practice skills in online learning are lack of face-to-face interaction thus, lack of real-life practical situations. Often, online learning does not provide the opportunity to directly apply the knowledge gained in real-life situations, which can limit the opportunities to develop practical application skills (Xhaferi and Xhaferi 2020). Therefore, science education researchers have become increasingly concerned with the performance assessment of laboratory work (Bekalo and Welford, 1999). The assessment of students' manipulation skills is important in that it provides students with an opportunity to demonstrate their manipulation skills and understanding of processes and concepts through doing lab activities. Aladejama and Aderibigbe (2007), stated that the student's academic performance is positively correlated with the science laboratory environments.

Today, in the face of dynamic changes in the global labour market, practical skills play a key role in the effective functioning of individuals and organizations. They influence employees' efficiency, innovation and adaptability. Students with well-developed practical skills can solve problems, make good decisions and quickly and effectively achieve objectives. This work, therefore, determines whether the practical lab sessions are effective in filling the gap in students' practical skills after the pandemic era. It further investigates how the development of cognitive abilities, ethical considerations, and interpersonal skills of students during the session is conveyed considering the domains of learning as prescribed by MQA. This research encompasses 25 participants from the Diploma in Microbiology program who were involved in this research from the School of Biology, UiTM Negeri Sembilan Branch, Kuala Pilah Campus. The limitations that have been imposed on students in practical molecular biology skills acquisition during the COVID-19 pandemic inspired this study. Forcing students to adapt to online classes inevitably offered them little room for practical laboratory work, which is vital in building up practical molecular technique's competencies. In the light of this challenge, the present study provides information concerning the influence of practical lab sessions on skill acquisition of students after the lockdown amidst the pandemic, showing how significant impersonal training is in gaining adequate laboratory skills.

Methodology

Study Design / Method

The study design used in this research was an action correlational design, which was selected because it is particularly well-suited for understanding the relationship between students' theoretical knowledge gained through online learning during the COVID-19 lockdown and their practical skills acquired in post-lockdown practical training hence this is non-experimental research that did not control for any variables (Creswell, 2008). The action component of the study allowed for direct intervention through practical laboratory sessions, providing an opportunity to observe and measure improvements in students' performance. The correlational aspect enabled us to assess the strength and direction of the relationship between students' initial theoretical understanding and their subsequent mastery of practical laboratory skills. This design is appropriate because it allows us to examine real-world educational interventions and their immediate impact on student learning without manipulating the variables, thus reflecting a natural learning environment.

A face-to-face practical molecular laboratory session was organized for second-year Diploma in Microbiology students at Universiti Teknologi MARA (UiTM), Negeri Sembilan, Kuala Pilah Campus in January 2022 to test the students' molecular laboratory practical skills, particularly on (i) understanding on the usage of molecular laboratory equipment, (ii) molecular laboratory protocols and procedures, and (iii) molecular techniques and terminology. The plan is to evaluate the molecular laboratory skills of the undergraduate students who were unable to experience practical laboratory session due to the COVID-19 pandemic lockdown. During the lockdown period, the students learned the subject theory through online sessions and this study was conducted after the lockdown period ended. During this experiment their molecular laboratory skills ability based on the theory learned online were put to test with a view to identify areas of deficiency and assess which areas are suitable to be understood with and without practical experience.

Study Population and Sample Size
The study was conducted during a practical molecular laboratory session in Molecular Laboratory in UiTM Negeri Sembilan, Kuala Pilah Campus (UiTMKP) and the source population for this study was students of year two enrolling Diploma in Microbiology, Faculty of Applied Sciences, UiTM Negeri Sembilan, Kuala Pilah Campus. The target sample was chosen based on the subject enrolment of the General Molecular Biology course which covers six topics including Gene Structure, DNA Cloning, Gene Expression, DNA Hybridization, Polymerase Chain Reaction and DNA Sequencing.

Instrument of Data Collection
Two instruments were employed in this study. The first instrument was evaluating the performance skill of 25 randomly selected students enrolling in the General Molecular Biology course using the skill performance rubric developed by the lecturers (see method supplement). The evaluation focused on three core manipulative laboratory tasks: identifying basic molecular biology laboratory equipment, accurate and precise use of tools such as the micropipette, thermocycler, and vortex machine, and measuring weights and volumes. These tasks represent essential laboratory practices for undergraduate microbiology students, as they are foundational skills required in most microbiology courses (Joji et al., 2022). Each student's practical skills were assessed using the rubric, with evaluations conducted by two independent raters. The inter-rater reliability was calculated using the Spearman correlation coefficient, resulting in a statistically significant rho of 0.80 ($p = 0.000$) at the 0.01 level, indicating good reliability (Gliner et al., 2009).

The second instrument was a questionnaire distributed to students before and after their participation in the practical molecular laboratory session. The questionnaire was divided into three categories: (i) Identification and Usage of Lab Equipment, (ii) Laboratory Protocols and

Procedures, and (iii) Understanding of Molecular Techniques and Terms. The closed-ended questions were designed using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Instrument Validation

To ensure the validity and reliability of the questionnaires used in this study, a multi-step validation process was undertaken. First, content validity was assessed by consulting a panel of three senior lecturers in the field of Biology, who reviewed the initial draft of the questionnaires. The aim was to ensure that the questions were relevant, clear, and comprehensive in covering the aspects of practical skills being measured. Feedback from the panel was used to refine the wording, structure, and focus of the questions, enhancing the instrument's alignment with the study objectives.

Following this, a pilot study was conducted with a small group of students similar to the target population to test the clarity, coherence, and practicality of the questionnaire. This pilot group provided responses and additional feedback on any ambiguities or difficulties encountered while completing the questionnaire. Based on their input, adjustments were made to improve the wording and ensure that the questions were easily understood. The pilot study also helped to confirm that the length and format of the questionnaire were appropriate, reducing the likelihood of respondent fatigue or misinterpretation**.**

The reliability of the questionnaire was further examined by calculating Cronbach's Alpha, which yielded a high value of 0.9, indicating strong internal consistency (Gobaw and Atagana, 2016). This demonstrated that the items within each section of the questionnaire were effectively measuring the same underlying concept and that the instrument was reliable for use in the main study. The final version of the questionnaire, therefore, represented a carefully validated tool aimed at accurately capturing students' practical skills in molecular techniques.

Data Analysis

The data collected in this study was analyzed using SPSS statistical program version 27. Three analyses were included namely Pearson correlation to determine the significant relationship between three categories formulated testing on students' molecular laboratory practical skills. Pearson correlation was used to determine if there was a significant relationship between two variables (questionnaire result of before and after attending the practical molecular laboratory session) providing numerical value between -1 and 1 which this coefficient indicated the strength of the relationship and signified its direction. The non-parametric Kruskal-Wallis test was employed to compare the means of the total score of practical molecular laboratory session among the participants differentiated by the student's performance before and after attending the lab session. A significance level of $p < 0.05$ was considered significant in this test. Groups that showed significant results in the Kruskal-Wallis test underwent further analysis using post-hoc tests, specifically the Mann-Whitney test. This test compared the mean total score between each pair of groups. The p-value obtained from the Mann-Whitney test was compared to the Bonferroni-corrected significance level of 0.05 divided by the number of pairwise comparisons to determine significant pairs.

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.

Results

The assessment of competencies and skills were collected from 25 Second-year Diploma in Microbiology students enrolling the General Molecular Biology course in UiTMKP. Due to the second wave of the Covid-19 that swept the country, schools and higher institutions did not open their doors for most of the year (KKM, 2021) forcing educators to conduct lab session virtually through video references and home activities. Forty-one Likert scale questions on a scale of 1 (Strongly disagree) to 5 (strongly agree) were distributed before and after the practical molecular laboratory session. However, the number of respondents was short in four for the after assessment (n=21). The questionnaire was divided into three categories of (i) Identification and Usage of Lab Equipment, (ii) Laboratory Protocols and Procedures and (iii) Understanding of Molecular Techniques and Terms (Table 1-3).

For category (i) regarding the identification and usage of lab equipment, Table 1 presents the results of students' responses on their ability to identify and use basic molecular biology laboratory equipment before and after attending the practical session. The competencies assessed include recognizing various lab instruments and understanding their proper use in molecular techniques. The result shows a tremendous amount of improvement (76% - 100%) with the majority transitioning from a neutral or disagree stance to agreeing or strongly agreeing with their competencies. For instance, there is a notable increase in the recognition of equipment like the vortex machine, centrifuge machine, tare the weighing machine, recognise the colour code of micropipette tips, loading sample in the well of agarose gel and understand the migration of DNA sample in gel electrophoresis following the practical molecular laboratory session. This shows the virtual learning process due to Covid-19 lockdown has hindered the proper understanding of lab equipment and development of skills among students as the absence of practical experience limits the students' progress (Doyle et al., 2023) despite the educator's effort to encourage students to conduct activities at home. It is impossible to help them maintain and develop their lab skills (Burgess and Sievertsen, 2020).

During the lockdown period of Covid-19, the laboratory protocols and procedures were explained to students virtually which require focus and student's ability to associate. In Malaysia, an overnight decision was made to migrate the education system to online activities where universities fortunately had already established online platforms to enable 'blended' learning; a hybrid teaching methodology combining e-learning with traditional classroom methods (Nuruzzaman, 2016). Table 2 summarizes students' self-reported competencies on laboratory protocols and procedures before and after practical sessions. The focus is on understanding aseptic techniques, sterilization processes, and safe handling of laboratory equipment. The data reveal a marked improvement in students' understanding of proper lab protocols, with many shifting towards "Agree" and "Strongly Agree" categories post-training. Particularly, awareness of aseptic techniques and the correct usage of gloves saw significant increases, underscoring the positive impact of practical exposure on procedural knowledge.

The huge improvement (28%-74%) in understanding laboratory protocols and procedures was achieved has shown students understand fully on the matter after experiencing them first hand. There is no complete replacement of practical components in a course, especially for achieving essential psychomotor outcomes and laboratory-based skills hence suggested mitigation action through catch-up technique-based open laboratory sessions once safe to do so (e.g., PCR, gel electrophoresis, microbial culture) to provide second chances for students who missed on learning specific techniques in-person during the pandemic (Ooi et al., 2022). Table 3 illustrates students' grasp of molecular techniques and terminology before and after participating in the practical session. It evaluates their understanding of key concepts, such as the use of supernatant, gel electrophoresis, and the term "aliquot". The understanding of molecular techniques and terms showed positive improvements with 71%-90% students strongly agreeing after attending the practical molecular lab session (Table 3). This is showing a 32%-69% increase in understanding compared to before attending the practical molecular lab session. Substantial growth in students' conceptual understanding could be seen, with most students reporting increased familiarity with terms and techniques. For instance, the ability to recall the function of gel electrophoresis and terms like "heat shock" showed considerable improvement, emphasizing the effectiveness of experiential learning in solidifying theoretical knowledge. Students are now able to view their sample on the agarose gel, transforming genes of interest into bacteria hosts and prepare the setup of electrophoresis gel. Competencies of students were clearly improved and further prove virtual laboratory delivery is challenging (Stenson et al., 2021).

Table 1
Students' response on the acquisition of competencies on Identification and Usage of Lab Equipment

Competencies	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	B	A	B	A	B	A	B	A	B	A
I can identify the lab bench.	0 0%	0 0%	0 0%	0 0%	3 12%	0 0%	6 24%	0 0%	16 64%	21 100%
I can differentiate the micropipette according to its measuring volume.	1 4%	0 0%	2 8%	0 0%	3 12%	0 0%	15 60%	0 0%	20 80%	21 100%
I can identify the gel electrophoresis machine.	4 16%	0 0%	3 12%	0 0%	9 36%	0 0%	9 36%	0 0%	0 0%	21 100%
I can identify the thermocycler.	3 12%	0 0%	11 44%	1 5%	8 32%	5 24%	4 16%	6 29%	0 0%	9 43%
I can identify the heating block.	3 12%	0 0%	3 12%	0 0%	6 24%	3 14%	8 32%	7 33%	5 20%	11 52%
I can identify the vortex machine.	3	0	4	0	8	0	5	0	5	21

	12%	0%	16%	0%	32%	0%	20%	0%	20%	100%
I can identify the centrifuge machine.	0	0	1	0	3	0	11	0	10	21
	0%	0%	4%	0%	12%	0%	44%	0%	40%	100%
I know the term tare while using the electronic weighing machine.	3	0	1	0	8	1	4	2	9	18
	12%	0%	4%	0%	32%	5%	16%	10%	36%	86%
I know the components involved in preparing an agarose gel.	3	0	4	0	10	1	6	5	2	15
	12%	0%	16%	0%	40%	5%	24%	24%	8%	71%
I know the type of experiment that will be conducted using a thermocycler.	5	0	5	0	10	6	4	6	1	9
	20%	0%	20%	0%	40%	29%	16%	29%	4%	43%
I know the function of heating block.	3		6	1	6	2	6	4	4	14
	12%	0%	24%	5%	24%	10%	24%	19%	16%	67%
The micropipette tips have a color code similar to the micropipettes.	5	0	2	0	15	1	1	1	2	19
	20%	0%	8%	0%	60%	5%	4%	5%	8%	90%
I am aware that the heating block is a substitute to the water bath.	2	0	4	0	10	4	3	5	5	12
	8%	0%	16%	0%	40%	19%	12%	24%	20%	57%
I will use vortex machine to separate the supernatant and pellet from a cell suspension.	4	3	3	4	5	2	12	4	1	8
	16%	14%	12%	19%	20%	10%	48%	19%	4%	38%
I will use centrifuge machine to mix the PCR component in a PCR tube.	3	3	4	1	6	3	9	4	3	10
	12%	14%	16%	5%	24%	14%	36%	19%	12%	48%
I will use 100ul micropipette to load 3ul of sample in the well of an agarose gel.	7	10	5	0	9	3	4	1	0	7
	28%	48%	20%	0%	36%	14%	16%	5%	0%	33%
I know how to dissolve agarose powder	1	0	8	1	10	4	5	7	1	9

(electrophoresis gel) in addition to using a microwave.	4%	0%	32%	5%	40%	19%	20%	33%	4%	43%
I know how to load my sample in the well of the agarose gel.	3	0	4	0	11	0	6	4	1	17
	12%	0%	16%	0%	44%	0%	24%	19%	4%	81%
I need to heat agarose solution until it boils.	1	4	4	0	13	3	2	5	1	9
	4%	19%	16%	0%	52%	14%	8%	24%	4%	43%
The migration of DNA sample in gel electrophoresis is from negative to positive direction.	2	1	1	1	9	0	7	3	6	16
	8%	5%	4%	5%	36%	0%	28%	14%	24%	76%
The DNA sample degrades if it is not kept in a 4 Celsius fridge.	1	0	7	1	6	3	8	7	3	10
	4%	0%	28%	5%	24%	14%	32%	33%	12%	48%
It is mandatory to keep the DNA sample in -80ºC freezer.	4	0	4	2	11	10	6	3	0	6
	16%	0%	16%	10%	44%	48%	24%	14%	0%	29%

**Before (B) and after (A) attending the practical molecular laboratory session*

Table 2
Students' response on the acquisition of competencies on Laboratory Protocols and Procedures

	Competencies	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
		B	A	B	A	B	A	B	A	B	A
1	I should wear gloves during molecular lab sessions.	0	0	0	0	1	0	6	0	18	21
		0%	0%	0%	0%	4%	0%	24%	0%	72%	100%
2	Contamination can occur from talking/saliva alone.	1	1	1	1	6	2	8	2	9	15
		4%	5%	4%	5%	24%	10%	32%	10%	36%	71%
3	I know the meaning of aseptic techniques.	1	0	2	0	1	0	9	2	12	19
		4%	0%	8%	0%	4%	0%	36%	10%	48%	90%
4	I know how to sterilize a lab bench.	0	0	1	0	5	0	12	1	7	20

		0%	0%	4%	0%	20%	0%	48%	5%	28%	95%
5	I know how to handle/hold a micropipette.	1	0	1	0	8	0	11	2	4	19
		4%	0%	4%	0%	32%	0%	44%	10%	16%	90%
6	Do you need to sterilize the vortex machine before using it?	2	6	2	3	14	2	2	2	5	8
		8%	29%	10%	14%	56%	10%	10%	8%	20%	38%
7	Do you need to sterilize the centrifuge machine before using it?	3	6	6	3	6	2	4	3	6	7
		12%	29%	24%	14%	24%	10%	16%	14%	24%	33%
8	I need to prepare a beaker with Dettol solution for my used micropipette tips.	2	0	4	1	12	6	5	3	2	11
		8%	0%	16%	5%	48%	29%	20%	14%	8%	52%
9	I need to use a laminar air flow cabinet to prepare my sample.	1	2	2	2	6	6	10	3	6	8
		4%	10%	8%	10%	29%	24%	40%	14%	24%	38%

**Before (B) and after (A) attending the practical molecular laboratory session*

Table 3
Students' response on the acquisition of competencies on Molecular Techniques and Terms.

	Competencies	**Strongly Disagree**		**Disagree**		**Neutral**		**Agree**		**Strongly Agree**	
		B	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**
1	I can recall the term supernatant.	2	0	1	0	5	0	10	4	7	17
		8%	0%	4%	0%	20%	0%	40%	19%	28%	81%
2	Molecular components/reagents are sensitive to temperature.	1	0	0	0	5	0	11	2	8	19
		4%	0%	0%	0%	20%	0%	44%	10%	32%	90%
3	I can recall the gel electrophoresis machine usage in molecular experiments.	2	0	1	0	5	0	10	3	7	18
		8%	0%	4%	0%	20%	0%	40%	14%	28%	86%

4	I remember the components involved in agarose gel preparation.	3	0	4	0	9	0	7	6	2	15
		12%	0%	16%	0%	36%	0%	28%	29%	8%	71%
5	I remember the term host bacteria and transformation process.	0	0	1	0	4	1	14	5	6	15
		0%	0%	4%	0%	16%	5%	56%	24%	24%	71%
6	I remember the function of a vector.	0	0	1	0	5	0	14	4	5	17
		0%	0%	4%	0%	20%	0%	56%	19%	20%	81%
7	I remember the need for gel star solution.	2	0	4	0	14	2	4	7	1	12
		8%	0%	16%	0%	56%	10%	16%	33%	4%	57%
8	I can recall the term heat shock.	2	0	4	1	10	4	4	5	5	11
		8%	0%	16%	5%	40%	19%	16%	24%	20%	52%
9	I am familiar with the term aliquot.	2	0	4	1	12	1	6	2	1	17
		8%	0%	16%	5%	48%	5%	24%	10%	4%	81%
10	I know how to view my sample on the agarose gel.	1	0	4	0	8	0	9	4	3	17
		4%	0%	16%	0%	32%	0%	36%	19%	12%	81%

**before (B) and after (A) attending the practical molecular laboratory session*

Table 4 provides the results of a laboratory performance test, comparing students' practical abilities before and after the practical sessions. The scores reflect competencies in identifying lab equipment, conducting aseptic techniques, and handling molecular lab tools. The score was evaluated out of 80 marks. The table shows a clear enhancement in overall scores post-training, with the mean scores for "Identifying the molecular lab equipment" (4.74±0.6) and "Handling of molecular lab equipment" (4.62±0.68) showing the most significant increases. These findings support the idea that practical experience is crucial for skill development in molecular techniques, bridging the gap between theory and practice. Positive improvement is justifying that the courses relating to laboratory session require practical training as course in molecular biology as subjects like i.e: biomedical sciences, involve understanding of theory, and competence in practical techniques and lab practice (Dudley and Matheson, 2024). Students were found to have improved the most in the ability to handle molecular lab equipment as this is seen as quite impossible to master from virtual learning. Virtual learning sometimes is incompatible with materials taught in class, especially laboratory-based courses as opposed to humanities and social studies rather than scientific materials such as engineering and medical science that entail practicing (Nahas et al., 2021). Additionally, key challenges of virtual learning include issues with internet connectivity, the use of technology, distractions from home life, reduced social interactions, difficulties in maintaining concentration, lack of motivation, and concerns about mental well-being.

Table 4
Laboratory performance test result on practical session

	Weight of score	Before Session			Weight of score	After Session	
		N	Mean	Std. Deviation	N	Mean	Std. Deviation
Identifying the molecular lab equipment	30	25	3.48	1.23	25	4.74	0.60
Conduct aseptic technique	10	25	3.52	1.02	25	4.55	0.82
Handling of molecular lab equipment	15	25	3.15	1.02	25	4.62	0.68
Function of molecular laboratory equipment	25	25	3.13	1.19	25	3.88	1.52
Total	80		13.28			17.79	

Table 5 highlights the statistical significance of changes in students' performance on practical skills tests before and after the practical session, analyzed using a t-test. The results show a statistically significant difference ($p < 0.005$) in skill performance before and after the sessions, confirming that the practical experience effectively improved students' practical molecular skills ($p<0.005$). The substantial increase in mean scores illustrates the tangible benefits of practical training in molecular biology education. According to Scott et al. (2017) molecular biology is one area of biology which could benefit from active teaching as much evidence (Marbach-Ad and Stavy 2000; Southard et al.2016) showed student perceived molecular biology as difficult due to specialised language and complicated laboratory techniques. Since the students involved in this experiment have experienced online lectures before attending the practical lab session, students were able to cross-reference between theory and practice and become active self-learners.

Table 5
Skill Performance Test before and after ($p<0.005$) the practical session

Session	N	Mean	STDV	Among session	P
Before (B)	25	13.8	1.23	Between B and A	0.0001
After (A)	25	17.79	0.6		

The pressure to continue the learning process during the disruption caused by the COVID-19 pandemic has increased the use of online teaching or "pandemic pedagogy," allowing for the continuation of education while maintaining social distancing. From one perspective, online learning has benefits, particularly in leveraging technology in the digital era to improve students' understanding. For example, the use of virtual and augmented reality technologies has been found to enhance students' motivation to learn basic concepts, thereby improving academic achievement (Chiu et al., 2021). Additionally, online teaching promotes green technology by reducing the use of harmful chemicals in laboratory settings. However, online instruction lacks key elements of learning, such as the acquisition of accurate and precise experimental techniques, the ability to troubleshoot equipment and data collection issues, and exposure to technical errors that may affect experiments (Delgado et al., 2021). Therefore, integrating online learning with practical skills should be the focus of future teaching practices. This approach is supported by Sarmouk et al. (2019), who found that online preparatory activities before practical sessions led to fewer errors in the lab and increased students' confidence and promote active self-learners.

Discussion

Second-year Diploma in Microbiology students in UiTM Negeri Sembilan sent on lab sessions received a substantial boost in their molecular biology skills. Quite surprisingly, the students tremendously increased their competencies mainly in areas such as identifying laboratory equipment, understanding protocols, and applying molecular techniques, which clearly show that hand-on practical work is the key to scientific education.

The data shows that trainees, who engaged themselves in the practical courses, had made significant progress in their practical skills in contrast to their prior level of achievement. This is consistent with earlier works that stress the need for practical learning to science education. The study's results demonstrate that young doctors who studied theoretical knowledge alone, received throughout the pandemic through online platforms, are not enough for understanding the psychomotor skills required in a laboratory. Doyle et al (2023), also draws attention to the fact that the pandemic led to the degradation of students' laboratory skills thus there was a need for face-to-face training to the students to make their practical competencies.

The comparison in terms of prior and state of students’ performance before the practical lab sessions and also after revealed a huge distinction between online and traditional laboratory settings. While online learning was a good way for students to acquire the basic concepts of subjects, it did not give them enough chance to put into practice the knowledge learned in the laboratory. In promoting the principal that virtual learning is not capable of fully replacing the tangible and interactive factors of laboratory education, the study has shown that students are not fulfilled in their skill development during the pandemic (Nahas et al., 2021). The implications of these observations for the contours of the forthcoming educational approaches are revolutionary. With the rapid emergence of a blended learning model, a proper mix of practical practice and online coursework is absolute. Teachers should opt for a blended syllabus which accounts for the use of virtual simulations together with practical lab activities to ensure that students are acquiring the necessary practical skills. In addition, preventive action like catch-up laboratory sessions to fill gaps for those students who have had disruptions would be crucial to precisely address the epidemic-related skill shortages.

Despite offering some brand-new perspectives, this report should start with its own shortcomings. The sample tested was rather short and was the singular one used at that place, that can be the reason that this finding is not fully applicable to the general audience. The follow-up research can be extended to a larger, more diverse cohort that could help to verify the findings in other educational settings. On top of that, those studying practical skills through practical training could also be monitored for more extended periods. Learning exercises that set students up to help each other and that involve the uses of augmented reality could perhaps be other resources that would boost the learners' engagement and skills.

Summing up, the research does not only strongly underline but reconfirms the critical role of practical teaching in the teaching of science students in the area of molecular biology. Schoolteachers, through the utilization of active learning techniques, can easily prepare students for the real-world scenarios encountered in the scientific sphere as well as nurture the skills that they will utilize everywhere.

Conclusion

This research confirms the value of practical training in developing the molecular laboratory skills of students that were affected by the COVID-19 pandemic. The improvement noted in students' ability to identify, handle and comprehend molecular machinery and techniques elucidates the importance of practical classes within the coursework. Therefore, it is important to prepare students with active training methods instead of just lecturing, more so for the scientific oriented degree programs. Furthermore, research needs to be conducted on the retention of skills learned via doing and the combination of conventional and online methods of learning. This study builds on the literature available on the need for practical laboratory sessions to enhance learning in the molecular biology degree programs. The results show the improvement of the skills of the students after the engagement in the laboratory addressing the need of teachers and mangers to devise teaching strategies that integrate practical classes with distance learning programs for the efficient training of students in the course of Molecular Biology.

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Method Supplement

Rubric for laboratory performance test

Criteria	0: none	1: very poor	2: poor	3: average	4: good	5: excellent
Identifying the molecular lab equipment	Participant could not identify all the molecular lab equipment.	Participant could only identify 1 of the molecular lab equipment.	Participant could identify 2 of the molecular lab equipment.	Participant could identify 3 to 4 of the molecular lab equipment.	Participant could identify up to 5 molecular lab equipment.	Participant could identify all of the molecular lab equipment.
Conduct aseptic technique	Participant could not conduct correct aseptic technique	Participant has very poor ability to conduct aseptic technique	Participant has poor ability to conduct aseptic technique	Participant has average ability to conduct aseptic technique	Participant has good ability to conduct aseptic technique	Participant has excellent ability to conduct aseptic technique
Handling of molecular equipment	Participant could not handle all the molecular equipment	Participant could only handle 1 of the molecular equipment but with incorrect technique	Participant could only handle 1 of the molecular equipment with correct technique	Participant could only handle 2 of the molecular equipment, some with incorrect technique	Participant could handle 2 of the molecular equipment with correct technique	Participant could handle all the molecular equipment with excellence and correct technique
Function of molecular equipment	Participant do not know the function of all the equipment	Participants know the function of only 1 equipment	Participants know the function of 2 equipment.	Participants know the function of up to 3 equipment.	Participants know the function of up to 4 equipment.	Participants know the function of all equipment perfectly.