The Current Effects of Automation on The Clinical Laboratory Workforce Among Sectors: A Case Study in Libya from 2020- 2021

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Abstract

As the automation system has advanced, there has been a wave of concern that lab automation will replace technicians. This paper aims to investigate the current impact of automation on the number of laboratory technicians, with special consideration given to knowing the current level of automation in the chemistry and hematology laboratories in both sectors. Four months of data collection using field visits and postal questionnaires that included demographics of laboratory technicians and types of automated analysis systems. Fully automated analyzers were positively associated with the number of technicians in the chemistry departments of the private sector (P = 0.03). However, the strategy adopted by the two sectors, which was based on not introducing pre- and post-analysis automation systems, contributed to its lack of impact on the laboratory workforce. Thus, manual labor is not dispensed with in all laboratories, allowing for multiple job roles for the laboratory workforce.

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Key words
laboratory automation; technicians; Libya.

I. Introduction:

Automation refers to the mechanization of duties performed by analyzers to reduce human intervention. By automating the repetitive and time-consuming manual processes involved in laboratory testing, automation in clinical laboratories has reduced human error, allowing laboratory technicians to devote more time and energy to quality assurance, which results in faster diagnosis and patient management. Although analytical automation has been around for more than 50 years and non-analytical automation began in the 1990s, which uses robotics to process samples and data analysis; fully automated analyzers were introduced in Libya only 20 years ago. The application of fully analytical automation has expanded in diagnostic lines such as clinical chemistry, immunochemistry, and hematology, but its application in diagnostic microbiology and histology has proceeded much more slowly, and many activities still require a significant manual workload.

Laboratory automation relied during its progress on three primary lines (hardware automation, LIS / LIMS laboratory information (management) systems, and pre-and post-analytical automation). The implementation of each level of automation varies depending on the demand, needs, and the main reason for its implementation [1]. Laboratory automation can be categorized according to the complexity of the hardware integration, e.g., when the analyzers are stand-alone it is classified as no automation. When the analyzer is partially connected to pre-analysis workstations it is defined as partial automation. While linking the automated analysis of the different sections such as hematology, and chemistry tests with pre-analytical automation (e.g., entering the sample, recording and sorting, uncapping, and centrifugation) and post-analysis steps it is defined as total laboratory automation (TLA) [2].

The approach to automation was introduced with introduction of first AutoAnalyzer. The AutoAnalyzer is a type of device that is used to measure a variety of chemical and biological properties. These machines are classified into (1) Continuous flow analysis, which is a form of sequential multiple analyzers in which samples are tested one by one and the results are presented in the same order [3], (2) a discrete analyzer, also known as random access analyzer, is selective and performs only the assays ordered on each sample. Centrifugal analyzers and random-access automatic analyzers use discrete analysis processes [4].

Most businesses created their own bench-mounted or floor-standing systems. The first was batch analyzers such as autoanalysers and centrifugal analyzers that perform the same test simultaneously on all samples, which waned at the end of the 1990s and was replaced by random access mode as the newer analysis tools [5].

There are several classes of laboratory science practitioners in the clinical laboratory workforce, with degrees ranging from associate to diploma to baccalaureate and higher. Members of the clinical laboratory workforce in Libya include medical laboratory scientists, developmental biologists, pathologists, first health technicians [laboratory technologists (MTs)], and second health technicians [medical laboratory technicians (MLTs)].

First health technicians and second health technicians have different educational requirements; first health technicians must have a Bachelor's degree in Medical Technology from a college or university that offers a four-year medical laboratory science program and must also complete a hospital course to gain a more comprehensive knowledge and practical base in analysis related to microbiology, blood bank, hematology, immunology, and biochemistry, among other things. Instead, laboratory technicians (second health technicians) have a diploma or an equivalent degree. Thus, for purposes of clarity, this paper will use the title "technicians or TECHN " instead of the previous job titles.

Laboratory automation is a global trend that aims to improve clinical laboratory workload management. However, there is very little data available on the type of automation present in laboratories and its impact on the laboratory workforce. Thus, the primary objective of this study is to investigate the impact of current automation on the workforce of clinical laboratories and determine the level of laboratory automation.

II. Materials and Methods

A. Study design

The data was collected through field visits to several private and public medical laboratories to observe the automation system in two sections, clinical chemistry, and hematology in addition to interviewing Schedule. Based on this information, an electronic questionnaire was created and submitted between December 2020 to March 2021.

B. Tools

The questionnaire was constructed and self-administered by the author of the study and was validated in a pilot study of 30 participants who did not participate in the final analysis. The first section of the questionnaire included the demographic information of workers (age, gender, place of residence, educational qualifications, and sector), followed by the other sections, which aimed to determine the characteristics of automation. As well as the percentage of clinical lab workers and the ratio of manual tests to automatic types used. The questionnaire used a variety of scales, including binary (yes or no), tripartite, and quartile scales, and some detailed questions. The questionnaire was written and distributed in Arabic to facilitate understanding and ensure reliable answers.

C. Statistical analysis

The data were entered using SPSS (IBM SPSS Statistics for Windows, version 25.0; IBM Corporation, Armonk, NY). Descriptive analysis was used to report the mean values, frequency, and percentage, chi-square test to measure the relationship between age, gender and sector.

Spearman to find the relationship between analyzers and the number of technicians and manual tests. The result is considered statistically significant when P values < 0.05.

D. Ethical approval

During in-person interviews, oral consent was obtained from all participating technicians prior to data collection. Additionally, laboratory supervisors permitted researchers to tour facilities and observe automation systems as part of the study.

III. Results

The study included 77 laboratories distributed across 27 Libyan cities, with 47.5% from the public sector and 51.3% from the private sector. Table I summarizes participant characteristics. The mean age of laboratory technicians was 28.75 years, with 73.8% holding bachelor's degrees. A significant age disparity was observed between sectors: technicians aged 20–25 years constituted 25% of private sector workers versus only 5% in the public sector. Females represented 54.9% of all respondents.

TABLE I. DEMOGRAPHIC CHARACTERISTICS OF WORKFORCE BY SECTOR.

Characteristics	**(n=122), (n %)**	**Sector**		**χ2**	**P-Value**
Age groups (Years)		Private (%)	Public (%)		
20-25	36 (29.5%)	30 (25%)	5 (6%)	**24.79**	***<0.05****
26-30	35 (%28.7)	19 (15.6 %)	16 (13%)		
31-40	39 (%32.0)	12 (10 %)	27 (%22)		
>40	12 (%9.8)	3 (2.4 %)	9 (7.4%)		
Gender					
Male	55 (%45.1)	30 (24.6%)	25 (20.5%)	**0.175**	***>0.05***
Female	67 (54.9%)	34 (27.8%)	27 (33%)		
Qualification					
B.Sc.	90 (73.8%)	49 (40%)	41 (33.6%)	**2.203**	***>0.05***
Higher Diploma	22 (18%)	12 (10%)	10 (8.2%)		
M.Sc.	10 (8.2%)	3 (2.4%)	7 (5.7%)		

*: Significant at P < 0.05.

(χ2) It shows the relationship between the demographic characteristics of the participants in the study and the sectors.

A. The shifts of laboratory workforce

Fig.1 represents the comparison between the number of workers in the public and private sectors. A significant difference ($P < 0.05$) was observed in both sectors. The results indicated that the clinical chemistry section of the public sector has the highest percentage of workers (4-

6) (53%) that work one day-shift. Whereas workforce shifts, (1-2) were the highest rate in the hematology labs of the private sector.

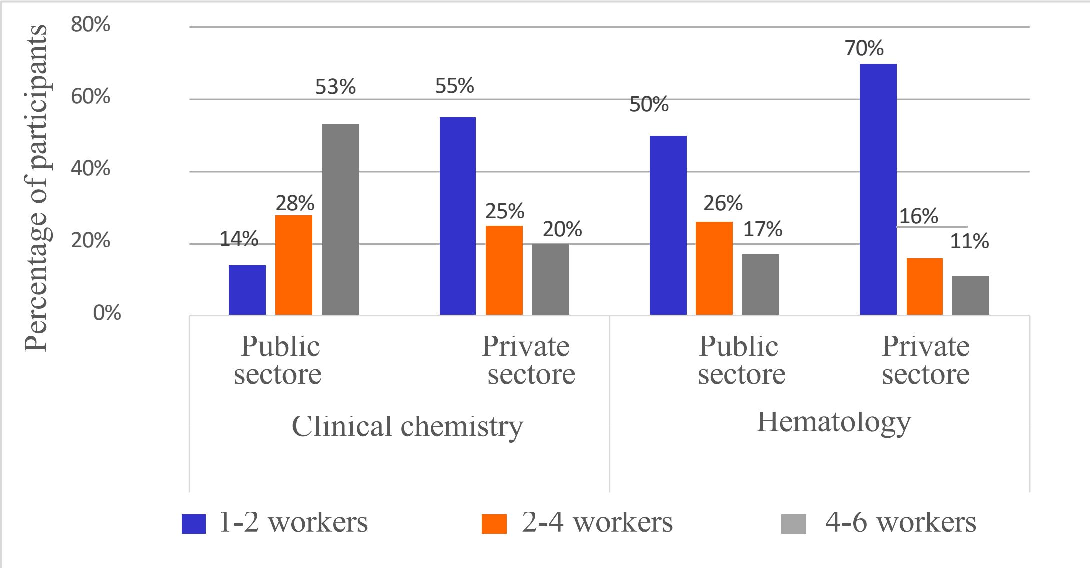

Figure1 . The histogram of responses to the question about how many technicians there are per shift in both sections.

B. Analysers and staff in chemistry section

The measurements of automation state, shifts, and manual tests in the chemistry lab are presented in Table II. The results showed 29.3% of public sector technicians reported having more than three fully automated devices, compared to 19% in the private sector ($P < 0.05$). For semi-automated analyzer usage, no significant difference was observed ($P = 0.983$). However, >40% of all participants reported performing ≥3 manual tests. Notably, manual performance of Bleeding Time (BT) and Clotting Time (CT) tests was reported by 70.7% of public sector workers and 87.5% of private sector workers. Regarding pre-analytical automation, only 10.3% of public sector laboratories versus 51.6% of private sector facilities implemented barcode systems. All participants confirmed centrifuge usage for blood sample separation.

C. The relationship between the number of analyzers and workforce in the sectors of chemistry section.

TABLE III shows a correlation between the workforce and analyzers, as well as the number of manual tests performed in the chemistry section. A direct association is found between fully automatic analyzers and the number of workers in the private sector (r= 349 *). The results in Fig. 2 indicate there is a weak positive relationship between the number of analyzers and the workforce in the chemistry lab of the private sector.

Using the binary scale (yes or no), the participants contributed to answering the questions that were asked based on prior observation of the laboratory devices in the two sections of both sectors. The collected data were then sorted according to the size of the analyzer, the type of operating system, and whether these systems were fully or semi- automated. TABLE IV shows semi-automated analyzers. Only benchtop was available.

Table II. THE AUTOMATION STATE, SHIFTS, AND MANUAL TESTIS SURVEY

Question type	Answers, n (%)							
	1		2		≥3		None	
	Private	Public	Private	Public	Private	Public	Private	Public
Q1- How many fully automated analyzers (the whole analyzing process from sample addition to results is done by instrument)?	19	35.9	29.7	25.9	18.8	29.3	1.6	5.2
Q2- How many semi-automated devices? (Pipetting of reagent and specimen, mixing is carried out externally by the technician).	18.8	29.3	28.1	22.4	31.3	12.1	21.9	36.2
Q3 - How many tests are conducted manually?	18.8	5.2	4.7	15.5	40.6	41.4	0	1.7
shifts	1-2		2-4		4-6		I don't know	
Q1- How many workers are in day shift?	6.5	29	13	13	11	25.4	0	2.4

Yes or no questions	**Yes answers**		
	Overall	public	private
IN THE CHEMISTRY LAB. Q1- Is BT, and CT performed manually in your laboratory?	97 (79.5%)	41 (70.7%)	56 (87.5%)
Q2- Are bar code systems applicable to you?	39 (32.0%)	6 (10.3%)	33 (%51.6)
Q3- Are blood samples subjected to the process of separation by centrifugation?	122 (100%)	58 (100%)	64 (100%)

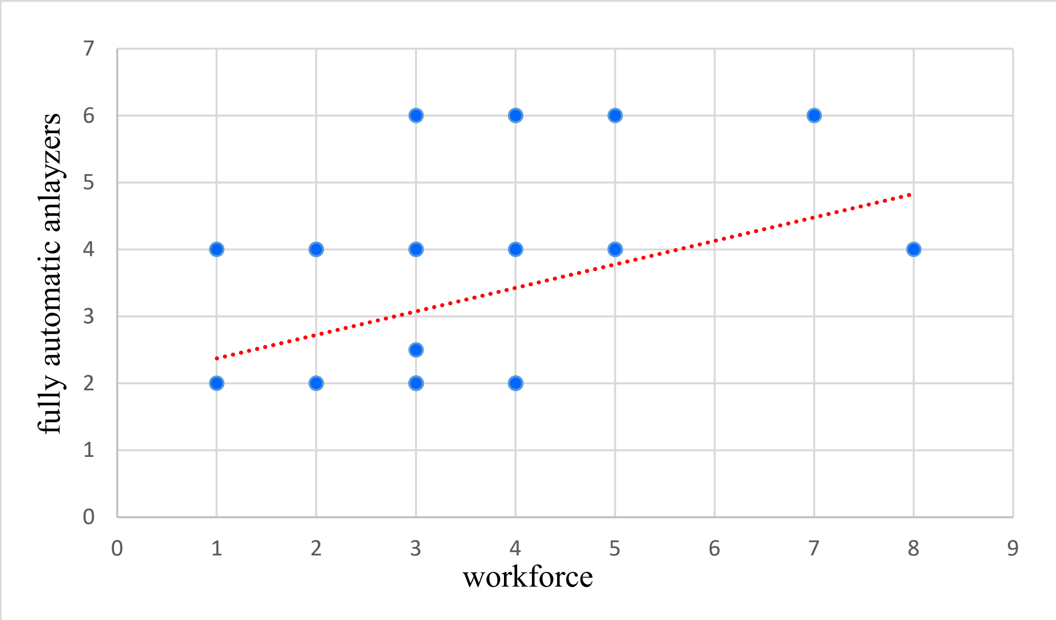

Figure 2: The relationship between the number of analyzers and workforce in the chimestry lab of private sector.

TABLE III . THE CORRELATION BETWEEN THE WORKFORCE AND ANALYZERS AND NUMBER OF MANUAL TESTS PERFORMED IN THE CHEMISTRY SECTION OF THE TWO SECTORS, WITH THE P VALUES AND NUMBER OF RESPONDERS.

Chemistry lab	**Number of workers in public sector**			**Number of workers in private sector**		
	r	P-value	n	r	P-value	n
Fully automatic analyzers	0.306	0.074	33	.349*	0.030	39
Semi- automatic analyzers	0.012	0.946	35	0.116	0.482	39
Manual tests	-0.031	0.860	35	0.054	0.743	39

TABLE IV. THE DEVICES WHOSE OPERATING SYSTEMS FOLLOW SEMI-AUTOMATIC SYSTEM IN CHEMISTRY SECTION.

Instrument	**Size**	**Operation Mode**	**Sector (n =122), n %**	
			Private	**Public**
The OPTI CCA-TS2	Bench-Top	continuous	12.5	3.4
COATRON M2	Bench-Top	Batch and Random Access	25	22.4
I Chroma	Bench-Top	Continuous & Random Access	25	19
Photo meter 4040	Bench-Top	discrete or continuous	42.2	32.8

Table V lists the devices that have a fully automated system that present in the sectors and indicates whether the instrument is bench-mounted or floor-standing, as they are all stand-alone instruments.

TABLE V. BASIC DETAILS OF DEVICES WHOSE OPERATING SYSTEMS FOLLOW FULLY AUTOMATIC SYSTEM IN CHEMISTRY SECTION.

Analyzer	**Size**	**Operation Mode**	**Sector (n =122), n %**	
			Private	public
AFLAS-6	Bench-Top	Multi-Channel	14.1	0
Konelab 20XT	Floor-standing	Random access	1.6	1.7
Cobas 8000	Bench-Top	Random access	1.6	1.7
Maglumi 800	Bench-Top	Continuous & Random Access	1.6	0
Mindray bs-230	Bench-Top	Random access	17.2	0
Elecsys 2010	Bench-Top	Continuous & Random Access	26.6	37.9
9180Electrolyte	Bench-Top	Random access	31.3	44.8
ABG analyzer	Bench-Top	Random access	48.4	39.7
STA Compact	Bench-Top	Random access	21.9	32.8
Yhlo unicell-s Poct reader	Bench-Top	Random access	9.4	0
Indiko	Bench-Top	Random access	0	1.6
Vidas	Bench-Top	Random access	20.3	15.5
iFlash 1800	Bench-Top	Random access	10.9	5.2
Kenza bio labo	Bench-Top	Random access	4.7	5.2
Cobas Integra 400Plus	Bench-Top	Continuous & Random Access	67.2	50
Alegria analyzer	Floor-standing	Random access	7.8	0
Easylyte Plus	Bench-Top	Random access	45.3	17.2
Cobas e411	Bench-Top	Random access	10.9	13.8
800 TS	Bench-Top	Random access	17.2	6.9
Cobas 601 C&E	Floor-standing	Random access	1.6	3.4
Fujifilm	Bench-Top	Random access	3.1	14.3

D. Analysers and staff in hematology section

In the hematology section, the result of answers about automation, manual tests, and duties was displayed in Table VI, which showed 39.7% and 50% of public and private sector workers, respectively, have one analyzer with no significant difference (P = 0.346). However, more than half of private sector workers are conducting at least one test manually. In terms of shifts, 1-2 workers on the day shift had the highest rate of the private sector participants (70.3%). In response to an open question about the manual tests performed in the laboratory, the majority of them referred to the ESR & blood film tests.

TABLE VI. THE PERCENTAGE OF RESPONSES TO THE QUESTIONS ON AUTOMATION, MANUAL TESTIS, AND SHIFTS IN HEMATOLOGY LAB

Question type	Answers, n (%)							
	1		2		≥3		None	
	Private	Public	Private	Public	Private	Public	Private	Public
Q1- How many fully automated analyzers?	50.0	39.7	7.8	12.1	7.8	8.6	34.4	39.7
Q2- How many tests are conducted manually?	56.3	37.9	21.9	34.5	21.9	25.9	0.0	1.7
	1-2		2-4		4-6		I don't know	
shifts	Private	Public	Private	Public	Private	Public	Private	Public
Q1- How many workers are in day shift?	70.3	50	15.6	25.9	10.9	17.2	3.1	6.9

TABLE VII summarizes the relationship between the fully automatic analyzers and the workers, and the manual tests were performed in the hematology labs of the two sectors. However, the results indicate that there is no statistically significant relationship between them (P> 0.05).

TABLE VII. THE CORRELATION BETWEEN THE WORKFORCE, ANALYZERS AND, THE NUMBER OF MANUAL TESTS PERFORMED IN THE HEMATOLOGY SECTION OF THE TWO SECTORS, WITH THE P VALUES AND NUMBER OF RESPONDERS.

Hematology lab	Number of workers in public sector			Number of workers in private sector		
	r	P-value	n	r	P-value	n
Fully automatic analyzers	-0.051	0.776	34	-0.156	0.350	38

nual tests	0.286	0.101	34	-0.046	0.782	38

When the workers were asked if they use these devices in hematology lab, users offer the following responses as shown in TABLE VIII.

TABLE VIII. THE DEVISES DATA IN HEMATOLOGY LAB

Instrument	Size	Operation Mode	Sector (n =122), n %	
			Private	Public
Sysmex KX-21	Bench-Top	Discrete, Random Access	4.7	3.4
Sysmex analyzer	Bench-Top	Discrete, Random Access	32.8	55.2
MYTHIC18	Bench-Top	Discrete, Random Access	0	20.7
SAMSUNG	Bench-Top	Discrete, Random Access	4.8	22

IV. Discussion

A total of 77 laboratories replied to this survey, a significant number of lab workers expressed the similarity of the use of different testing systems in the two sectors. The chemistry section has adopted fully automated and semi-automated systems that consist of continuous flow analysis and discrete analysis in both sectors. While the hematology laboratories utilize fully automated analyzers with discrete analysis. The laboratory workforce in both sectors consists of different individuals with roughly similar qualifications.

A previous report conducted by the Information and Documentation Center of the Libyan Ministry of Health between 2010 and 2018 confirmed an increase in the number of medical technology graduates by 11,611 out of the total number of graduates. Accordingly, technicians working in private laboratories increased and made up 70.3% of the total workforce, with a steady increase in the number of private laboratories from 166 laboratories in 2007 to 411 laboratories in 2018 [6], likely due to the increased workload as a result of civil wars and poverty that has led to the deterioration of the health system of the population and poor public services, as well as the emergence of capitalism in the country—all contributed to the maintenance of the current standards of services. This is consistent with our current survey, which found that private sector laboratories had a higher rate than the public sector, at 4%. Fresh graduates constituted 25% of the private sector workers, compared to 6% of the same group working in the public sector. In contrast, a Saudi Arabian study comparing two laboratories in terms of the impact of total automation on the workforce in clinical laboratories found that the workload in the laboratory increased steadily against the fixed number of employees and was estimated based on a 5% annual growth rate. That means the state of automation reduced the workforce by 30% {Al Naam, 2022 #828}. Women in this study represented an estimated half of the laboratory workforce, whereas in the United States, women have historically made up 75% of the clinical laboratory workforce historically [7].

Undoubtedly, it is important to understand the relationship between the number of technicians and the quality of equipment available in the laboratory. The more technologies, the easier the analysis and the faster the result, which may contribute to reducing the labor force in the laboratory. Al Naam et al. (2022) [8] argued that developments in laboratory automation in Saudi Arabia increased the laboratory workload steadily against the fixed number of employees and was estimated based on a 5% annual growth rate. That means the state of automation reduced the workforce by 30%. Contrary to our results where the highest percentage of technicians (4-6 workers) was in the chemistry lab in the public sector which has more than three fully automated analyzers versus (1-2 technicians) in laboratories of hematology which include at least one analyst in the private sector. The overcrowding of technicians in the public sector may be due to administrative corruption, and automation has no role. However, the fully automated analyzers were positively associated with the number of private sector workers (P = 0.03).

Several studies have described the impact of automation on the laboratory. It has been shown that automation of core laboratory systems (chemistry, hematology, and coagulation) reduces manual processing methods by 86% Antonios, et al. [9]. Although our public sector has moved ahead over the private sector in terms of the widespread use of fully automated devices, some tests are still performed manually, such as ESR and blood film tests in a hematology laboratory, BT, and CT in the chemistry lab. Furthermore, the presence surplus of technicians in clinical chemistry lab needs all point to a state of equilibrium and lack of interest in the global wave of anxiety related to automation and its impact on laboratory workers' jobs.

A previous UK review demonstrated the variety of automated analyzers on the market, with 12 large analyzers handling the workload and approximately 20 analyzers in total [10]. The current study confirmed the existence of a diverse range of fully automated analyzers performing various immunoassays in clinical chemistry laboratories in the Libyan market, with approximately 18 analyzers available for large workloads and a total of approximately 22 analyzers. The process of selecting laboratory equipment that can handle the workload, instrument quality, and operating system varied from one laboratory to another, but in general, the devices used in the public sector were very similar to those used in the private sector (e.g., Elecsys 2010, 9180 Electrolyte, ABG analyzer, and STA Compact were the most commonly used in chemistry laboratories for both sectors). They all follow random access analysis. In terms of small workload assays, although batch analysis is more cost-effective than random-access analysis, most operating systems for semi-automated analysts follow the newer system, which is random-access analysis. Although the current study accounted for the majority of analyzer automation found in laboratories, other differences, such as the number of tests performed or differences in HR policies, were not considered further. Despite these limitations, we believe that the findings of this study provide a useful baseline for assessing the impact of current automation on the clinical laboratory workforce.

V. CONCLUSION

In conclusion, this study highlights the current level of automation in the chemistry and hematology laboratories of both sectors, with special consideration given to the current impact of automation on the number of laboratory personnel. The results indicated that automation did not negatively affect the jobs of laboratory workers.

Recommendation

The current laboratories depend on a large number of employees. In addition to the presence of manual processes that allow the expansion of functional roles of the workforce in the laboratory. However, this does not excuse us from facing the challenges posed by the World Health Organization and ISO (International Organization for Standardization 15189), which require the presence of modern and sophisticated laboratories that use information technology in laboratory operations and in extracting results to give the results of examinations as quickly as possible to the doctor. However, due to global advances in laboratory automation, we stress the importance of pursuing technical education to acquire skills in artificial intelligence and laboratory informatics in addition to medical education, because a technician's environment is between human samples and assistive devices. Strong attention should be given to the field of research to increase the productivity of knowledge and raise skills that are unlikely to be dispensed with in the case of developing laboratories.

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