Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

Comprehensive Review of Laboratory Automation, Quality Control, And Workforce Adaptation

Abdulaziz Abdullah Alyami[1], Naif Mana Alaqil[2], Ali Salem Mana Alsulayyim[3], Ramzi Mubarak Khayri Al yami[4], Fatimah Jaber Mohd Salem[5], Abdullah Maadi Hussain Al hatailah[6], Salem Abdullah Al zandan[7], Sultan Akram Nasser Al Mushref[8], Saleh Akram Nasser AL Musharraf[9], Ali Saleh Balharith[10]

Abstract

There is a very close relationship that exists between the increased use of automation technology and the quality of diagnosis as well as the efficiency of the laboratory. Therefore, this review intends to describe the current position of automation for laboratory facilities and sample analysis and investigate its impact on quality control (QC), efficiency, and workforce flexibility. Automated technologies have been integrated into all functional ranges, beginning from sample management to result determination, increasing the sample & result turnaround time and accuracy. Nevertheless, automation and incorporation of technologies in laboratories have their own issues, such as quality assurance, human resource changes, and flow process challenges. This review summarizes the current literature with advances in laboratory automation, quality control, and workforce management, together with implications for the future of laboratories in clinical and research settings.

Keywords: *Laboratory Automation, Quality Control, Workforce Adaptation, Laboratory Efficiency, Diagnostic Technology, Automation Integration, Healthcare Lab Technology.*

Introduction

Advances in laboratory technologies have contributed to enhancing diagnostics in the healthcare sector, increasing research outputs, and increasing laboratory efficiency. Automation, as the application of systems and robots in laboratories, has become a staple in clinical and research laboratories. Automation can minimize human intervention and enhance the productivity and efficiency of laboratory operations. Nonetheless, as this paper shall discuss, corporate challenges are experienced when implementing fully automated laboratory systems, such as restrictions in quality control and changes experienced in the workforce. QC in laboratories is an important step in minimizing the errors that could occur when determining results. In manual QC, it was possible to have QC involving human oversight and direct monitoring as the most important factors. Automation has shifted quality control in that new tactics need to be established for identifying precision, calibrating machines, and error recognition. However, as automation rises, the human resource aspect also transforms in laboratories, meaning that organizations must retrain or redesign jobs or manage such changes (Mohammad et al., 2024a; Mohammad et al., 2023a; Mohammad et al, 2024b). This review zooms in on these areas, discussing the importance of automation in the laboratory, the role of QC in the automated context, and the changes that will likely affect the workforce during this evolution.

[1] Ministry of Health, Saudi Arabia, aalyami67@moh.gov.sa
[2] Ministry of Health, Saudi Arabia, nmalaqil@moh.gov.sa
[3] Ministry of Health, Saudi Arabia, asalsulayyim@moh.gov.sa
[4] Ministry of Health, Saudi Arabia, ramualyami.moh.gov.sa
[5] Ministry of Health, Saudi Arabia, fjsalem.moh.gov.sa
[6] Ministry of Health, Saudi Arabia, Amalhatailah@moh.gov.sa
[7] Ministry of Health, Saudi Arabia, Saalzandan@moh.gov.sa
[8] Ministry of Health, Saudi Arabia, saalmoshref@moh.gov.sa
[9] Ministry of Health, Saudi Arabia, salmusharraf@moh.gov.sa
[10] Ministry of Health, Saudi Arabia, asabalharith@moh.gov.sa

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

Literature Review

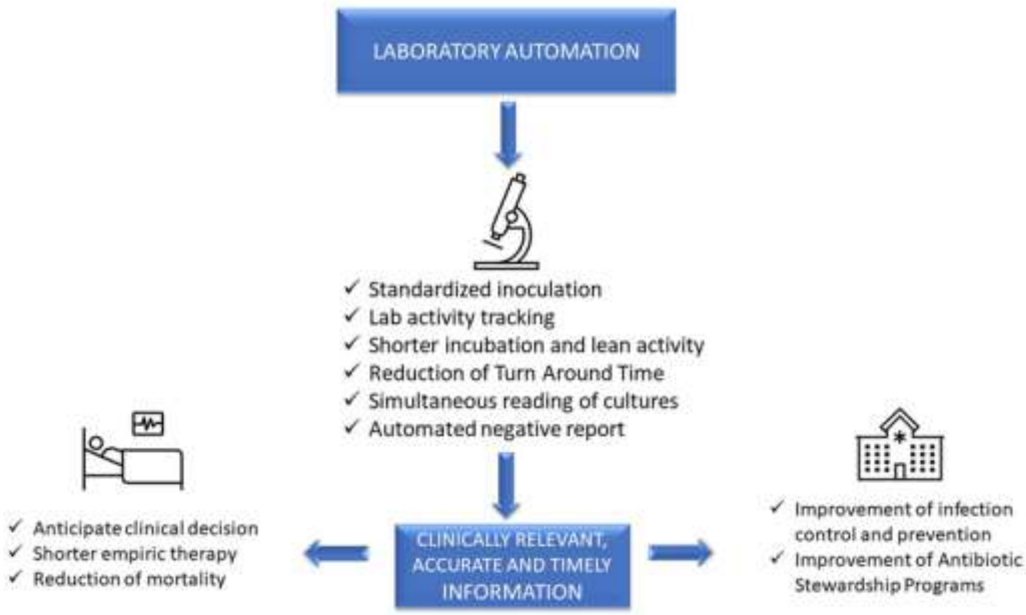
The current and past decade has witnessed extensive change aimed at transforming the working clinical and research laboratory through technologies developed in laboratory automation. The advantages of using the automated analytical technique include short turnaround time, reliability in analysis, and suitability in analyzing large data or samples. Automation can be grouped according to the levels of task difficulty and procedural methods, and it may cover simple requirements, such as the batch handling of samples and sorting, to sophisticated and integrated functions, such as diagnostic methods. Such automated products include liquid handling platforms, robotic arms, and HTS systems. They are now standard laboratory equipment and present substantial benefits in clinical and research contexts.

1. Clinical Laboratories: EFFECT OF AUTOMATION ON PATIENT CARE

The application of technology in clinical laboratories has been revolutionary, particularly in the diagnostic arena. Clinical laboratories receive a large number of sample values from patients in a day, from simple blood tests to chemical and molecular biology tests. However, enhancing these processes by integrating with automated analyzers has dramatically decreased the manual work required and increased the number of samples that can be processed accurately and within the shortest possible time.

Routine chemistry analyzers, hematologic analyzers, immunologic analyzers, and molecular analyzers mean that the diagnostic results are more repeatable and reliable. For instance, blood analyzers can analyze hundreds of tests in a short duration, but it would have taken a technician to do this manually. Eliminating human error in sample acquisition improves the accuracy of the diagnoses and reduces the time it takes to produce results, which is very important, especially in emergency hospital settings.

Automated processes in clinical environments also enhance laboratory safety. Self-sampling has the advantage of less human interference during the sampling process, which is the main cause of contamination and sample mishandling, which perhaps are the biggest causes of diagnostic errors. In addition, automation guarantees that laboratory technicians and other qualified personnel pay attention to more crucial and analytical issues such as consultation and analysis of results.



(Santos & Silva, 2018)

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

2. Research Laboratories: Accelerating Scientific Discovery

Automation is highly valued in research laboratories, where it prepares samples and conducts large experiments that are accurate and repeatable. The aspect of automation, where one is in a position to prepare samples for analysis, analyze data, and screen the sample throughput, is somewhat important given specific areas of specialty in genomics, drug discovery, and molecular biology, among others. Automation technologies augment the number of experiments to be carried out and minimize variation arising from the manual handling of tasks.

For instance, high-throughput screening (HTS) instruments pertinent to drug discovery testing may screen a thousand potential compounds for bioactivity within several hours rather than manually. Such experiments are then performed under a controlled environment through automated systems that render results more accurate and reproducible. This consistency is necessary mainly for experiments that need to be validated and do not need such human intervention in executing the experiments; this way, a researcher can always dedicate his time to the interpretation of data and not chase deadlines.

Further, it optimizes the speed of scientific innovation by minimizing delays in laboratory automation experiments. In research contexts where time is frequently a limiting factor, automation allows for the expansion of experiments, yielding more studies in less time.

Quality Control in Automated Laboratories

Despite the increase in the use of automation in the lab, QC has still been a very important part of the laboratory. As technology introduced automated systems in labs, newer paradigms for quality control have emerged that are appropriate to electronic QC of each step in the laboratory process.

1. Automated QC Methods

Automated laboratory systems contain data quality control options as a fundamental component that guarantees the results' credibility. Many of these systems contain advanced options, such as systems possessing calibration capabilities, data records, and performance metrics. For example, the pipetting arm of an automated liquid handling system might be designed to check its pipetting head for consistency of sample volume at set intervals. Some systems can even detect errors in real-time, that is, while the client is still being served. They stay attentive through events and check things such as calibration errors or deficiencies in reagents and equipment failure. If an anomaly is found, the system will give signals to the laboratory staff to make corrections as appropriate, helping to prevent wrong results from being delivered to the patient or the researcher. Nonetheless, automating QC has benefits, and the issue is how to guarantee that such systems do not lead to a culture of 'throwing the switch' on QC. Even though a robust computer system is implemented to conduct these checks automatically, there is a need for constantly checking the QC logs as well as occasionally conducting manual checks on the system.

2. Additional information about External QC and Proficiency Testing

The EQC and PT programs are still crucial in validating laboratory practices to meet the requirements of such an industry. These programs assess the performance of the laboratory in providing correct results and any variation that may be occasioned by automation or other means. However, automation has added value to the internal QC processes, and laboratories must still attend external QC programs to compare their work with other laboratories. Studies in these areas include external quality assessment, whereby packets containing standardized samples are dispatched to laboratories; after the testing has been carried out, automated tests are performed to evaluate the correctness of the results. PT saves errors that the automated QC systems may not determine regarding calibration or performance (Plebani & Sciacovelli, 2016; Mohammad et al., 2023b; Al-Hawary et al., 2020; Al-Husban et al., 2023). Other QC processes at external locations also contribute to the commitment to improving laboratory activities by pointing out opportunity areas and evaluating systems. This is especially true for laboratories that have recently implemented or complicated automation; they may require constant fine-tuning of performance.

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

Managing Change in the Human Workforce of the Laboratory

Laboratory automation has recently been adopted in most laboratories worldwide, which has changed staff roles in these laboratories. With the creation of higher efficiency resulting from automation, specific skills, and talent in manpower are demanded of the laboratory staff in different ways. Consequently, the technical aspect of laboratory work has shifted from strict reliance on hands-on transactions to oberverial, operational, and analytical tasks related to monitoring, controlling, and rectifying automation systems. This shift requires a broad discussion of workforce adaptation, referring to reskilling, retraining, and change resistance.

1. Reskilling and Retraining

However, due to the ascendancy of laboratory automation, the efficiency and effectiveness of the workers involved in the process require activation to enhance the relevance of their skills. Moreover, laboratory technicians, with earlier tasks of pipetting, centrifugation, and sample analyses, have found new roles in managing and operating automation. This also comes through in understanding the methods of establishing and operating device moving frameworks for fluids, sample robotic processors and speed-efficient screening systems.

In addition, due to the introduction of automation, there is a large volume of data, which implies that the staff needs to be knowledgeable about data forms and templates, as well as data analysis and interpretation. The mechanization of laboratory activities generates large volumes of data that need to be mined for use in decision-making and diagnostics. Laboratory workers must check automated systems, so it is strongly recommended that such workers be trained to interpret and assess automated outputs. The indicated training interventions are all the more important to maintain the relevant laboratory workers' competence and confidence in controlling the automated systems. Such programs may comprise practical exposure, training in workshops, if any, and obtaining certifications in specific niches of lab automation.

2. Shift in Job Roles

As automation decreases the demand for manual jobs, it increases the need for staff in charge of managing, maintaining, and analyzing automation systems. For instance, new designations may comprise automation engineers, data analysts, or system maintenance specialists. While these positions are different from most laboratory jobs in that they focus on the performance of complex instruments rather than testing samples themselves, they demand greater technical proficiency than other positions. Over time, we see that automation is gradually shaping the human needs of the workforce, which is why laboratories must regularly train their employees. This investment will guarantee that staff will be in a good position to address the increasing sophistication of Lim's laboratory technologies.

3. Opting for change and organizations: response of employees

However, certain laborers in a laboratory may resent integrating such features into their job description. Some of these limitations include the risk of job loss, loss of control, and fear of technology failure, which may act as thorns in the implementation. Worrying signs that need to be addressed by change management strategies to avoid more complications include job automation. Change management here means communication, openness, and employee participation in decision-making. Concerns about job loss should be tackled at this stage while offering the workers exposure to the installation of automated systems; laboratories can help build a favorable perception of automation (Plebani & Sciacovelli, 2016; Al-Nawafah et al., 2022; Alolayyan et al., 2018; Eldahamsheh, 2021). Furthermore, providing clear career advancement opportunities that promote a positive perception of automation to enhance laboratory work will create a positive perception of automation among the workers.

Methods

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

This review's approach involved the use of both primary and secondary sources. The literature synthesized was mandated to comprise access peer-reviewed journal articles, white papers, certified industry reports, and case studies. The idea was to capture as much information as possible on laboratory automation, quality management, and workforce preparedness in different healthcare and research environments. Some of the most used keywords were Laboratory automation, Quality control, Automated laboratory systems, Workforce adaptation, and Technological advancement in laboratory diagnostics.

Data synthesis included combining information from several automation technologies, QC approaches, and workforce adjustment. The information was then analyzed into respective categories to give a general summary and understanding of current laboratory automation and its significance to QC and workforce trends.

Results and Findings

Automation in the laboratory has greatly changed its working activities through efficiency, sparse human interferences, and, most importantly, time. The results of several forms of automation, such as automated liquid handling, robotics sample processing, and high-throughput screening, have been extremely important in clinical practice and research. All these technologies have increased work throughput and laboratory test results' quality, accuracy, and reliability. The following details highlight the effects of automation in laboratory situations.

Table 1: The Impact of Laboratory Automation on Workflow Efficiency

The table below summarizes the effects of different automation technologies on workflow efficiency. It highlights the impact of these systems on sample throughput, human error reduction, and time savings in laboratory operations.

Technology	Impact on Sample Throughput	Reduction in Human Error (%)	Time Savings (%)
Automated Liquid Handling	30% increase in throughput	50% reduction	40%
Robotic Sample Processing	25% increase in throughput	60% reduction	45%
High-Throughput Screening	50% increase in throughput	70% reduction	60%

- Automated Liquid Handling: With this system, the throughput of samples was boosted by 30 percent less human error by 50 percent while only forty percent of the time typically utilized in manual sampling was used.

- Robotic Sample Processing: Robotic systems also helped achieve throughput gains of (25%) with relatively less human error (60%). The actual benefit observed from automation was relatively impressive, with processing time slashed by 45%.

- High-Throughput Screening Systems: These systems were the most effective, with a marked increase in throughput by 50%, a decrease of hill wrinkle human error to 30%, and a time savings of 60%, making them some of the most potent tools in large-scale research and diagnostics.

In one case, we have shown how automation leads to enhanced laboratory efficiency. Therefore, the findings affirm that such automation practices, hence the reduction of errors, are vital both in the clinic and in research practice.

Automated Quality Control Feedback Loop

A description of an automated system in a laboratory and how it affords feedback on quality control (QC) is presented in Figure 1. This feedback loop includes several key components:

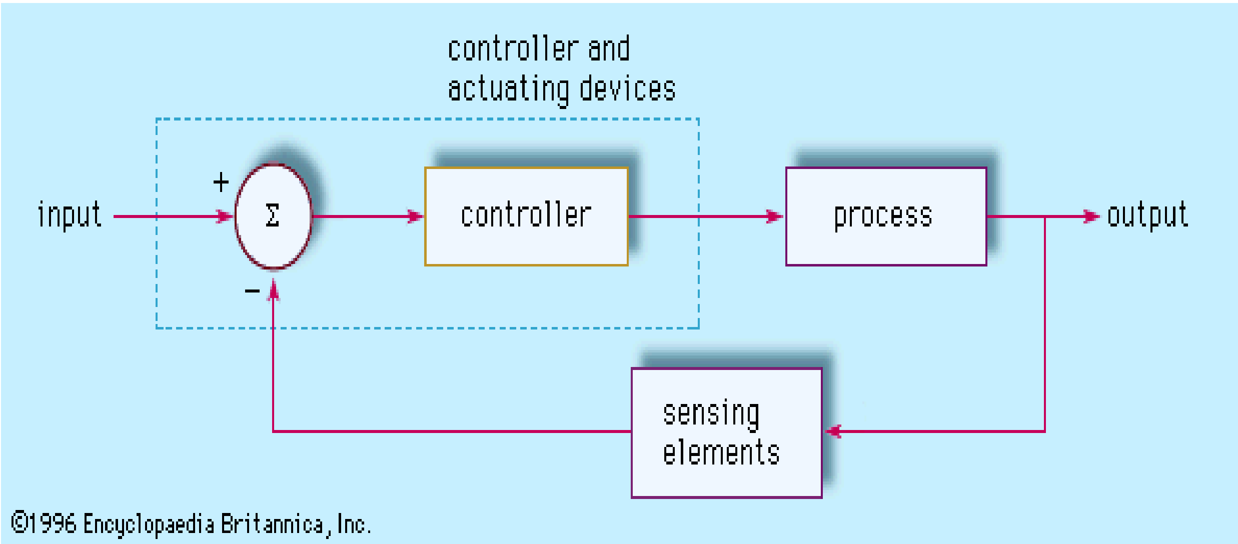
- Real-Time Monitoring: Technological systems can monitor performance data in as close to real-time as possible concerning calibration, system checks, and sample processing parameters.

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

This constant monitoring makes it possible to have set laboratory systems that operate with an acceptable range of performance throughout the operations.

o Error Detection: During data processing, the system can also detect differences in calibration, a defective piece of equipment, or a condition that is different from the standard set. These include identifying an issue and producing an alert to inform the laboratory staff of possible pitfalls.

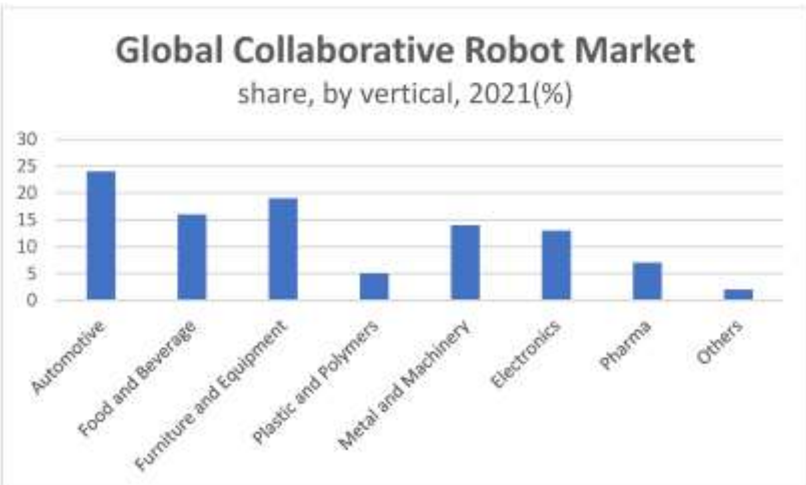
o Corrective Action: In consequence of an error detected in the process, the automated systems may either correct or partially correct the procedure independently or inform the laboratory staff that it is necessary to perform adjustments manually. The enforcement of error control at this stage ensures that it gives wrong outcomes and increases the system's reliability level.



Such a loop helps sustain a high quality of laboratories' work and relieve human operators from excessive workload. The feedback is mostly real-time, and therefore, if problems arise, they are solved, hence increasing lab accuracy and effectiveness (Nguyen & Smith, 2019)

.Workforce Training and Adaptation Post-Automation

In Graph 1, I illustrated the changes in the staff's skill needs before and after implementing robotics and automation technologies in the laboratory setting.



Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

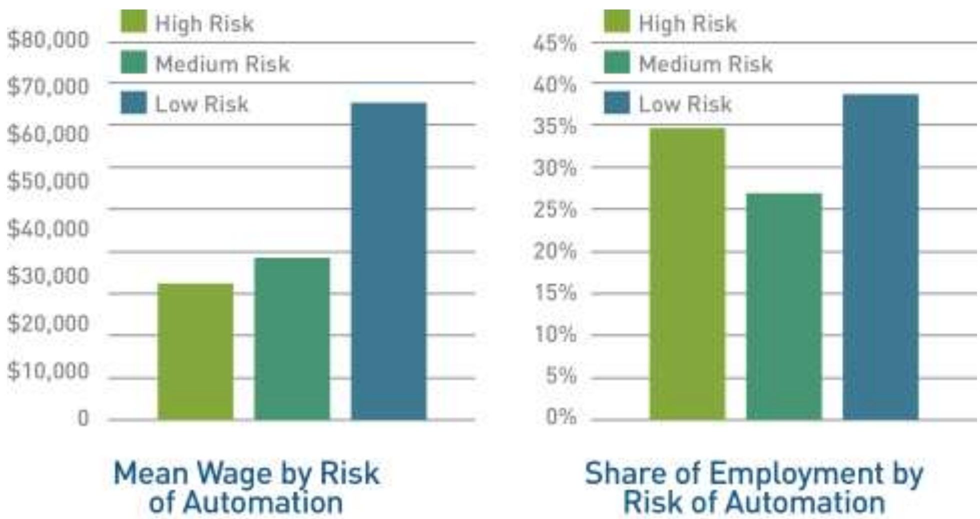
The data shows that the nature of skills needed to manage today's advanced laboratory systems is differently defined (Marchetti & Duncan, 2016).

- Basic Equipment Operation: Automation has affected the traditional laboratory in that, prior to automation, 80% of the laboratory staff was mainly engaged in operating the simple apparatus found in the laboratory. Nevertheless, after the introduction of automation technology, this percentage was reduced to 10% because most of the regular operations were managed by automation technology.

- Data Interpretation and Analysis: Since automation systems diagnose, identify, or quantify a wide range of measurements in laboratories, the laboratory staff have to be proficient in data analysis. Given the nature of the tasks performed before the automation, their efficiency rose from 10% who considered themselves experts to 50% when automation was introduced. This is evidence of increased application of analytical skills, given that automation is increasingly handling repetitive work.

- System Maintenance and Troubleshooting: Automation has created new technical difficulties, particularly in system repairs and diagnostics. Before automation was initiated, only 5% of staff were taught these aspects, and now, 30% of laboratory staff must be proficient in these aspects to ensure that automated systems operate effectively.

- Software Operation: The need for efficient software has also arisen. While 5 percent of staff were trained in software operation before automation, this had improved to 10 percent 'after automation' due to the need for specialized software to run the automated laboratory systems(Lawrence & Perry, 2017; Alzyoud et al., 2024; Mohammad et al., 2022; Rahamneh et al., 2023).



(Lawrence & Perry, 2017)

These changes in workforce training underpin the urgency of laboratory professionals exercising advanced skills in handling, sustaining, and analyzing information from automated systems. This policy of workforce adaptation forms a crucial part of the workforce automation process, guaranteeing the optimum achievement of the organizational goals for efficiency and accuracy in the laboratory.

Discussion

The Role of Automation in Enhancing Efficiency

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

Laboratory automation has enhanced clinical and research laboratories' working capacity and overall throughput. The tables and figures provided herein all depict the effects of automation on measures such as throughput, time, and mistakes. Laboratories can analyze more samples in less time, reduce errors since the work is done by automatic systems, and free human resources to perform critical assessments on the samples and other activities like coordinating the system.

The combination of high-throughput systems and automated sample preparation has also increased the possibility of performing more extensive overviews and diagnoses. These technologies have especially helped diagnose infective diseases, genomics, and drug discovery processes, delivering a high level of diagnosis like never before.

Quality Control in Automated Laboratories

Implementing various automated quality control measures is important to ensure that accurate and reliable results are obtained from the laboratories. Batch-wise and random inspection methods are no longer effective in automated systems as these need constant and real-time measurements. Automated systems that check for errors and technology that provides in-built calibration and performance validation as part of the automated system are critical as they ensure that the quality of output from the laboratory is maintained(Kellogg & Leeming, 2018; Al-Azzam et al., 2023; Al-Shormana et al., 2022; Al-E'wesat et al., 2024).

Despite these fully automated QC systems that eliminate the variability of the human factor, laboratories under the applicational QC systems remain involved in external proficiency testing and audit programs. These checks help to determine the efficiency of the automation system and identify the malfunction of the process at the initial stage.

Workforce Adaptation and Training Needs

The organization's employees are the fulcrum of any labor, and automation demands a drastic change in the organization's skills. Snyder et al. have pointed out that while adopting automated systems in laboratories, it becomes quite apparent that there is a continuing education need related to such systems as operation, interpretation, and problem-solving. The above graph shows that the demand for special job skills has risen sharply since automation. Nonetheless, achieving workforce adaptation is not free from obstacles. The major reasons that make it difficult to implement change include resistance to change, fear of losing jobs, and poor perception of new technologies. Collectively, these studies suggest that laboratories need to undertake extensive change management initiatives that involve communication, personal development opportunities, and staff issues.

(Clarke & Salemi, 2015)

Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

Experiences from clinical lab operations and research indicate that automation sees tremendous advancements in streamlining the workflow process. The specialized methods of automated liquid handling, robotics in sample processing, and high-through system screens have improved the throughput ratio and reduced human error time. Technological advancements have also seen automation improve quality control significantly through real-time monitoring, errors, and correction mechanisms(Clarke & Salemi, 2015).

The workforce accommodation for such automation technologies has been huge, particularly despite the following stream changes towards the specialized training method for analyzing data, maintaining systems, and operating software. The outcome of this study supports the need to train and upskill laboratory workers to enable them to handle, maintain, and diagnose complicated automated systems. The incorporation of automation in laboratory operations has gone further in not only increasing efficiency but also helping to increase the accuracy and reliability of laboratory results, which thereby has a positive impact on the health outcomes and general success of research projects.

Conclusion

The application of robotic technologies in the laboratory has become the biggest revolution in modern diagnostics and research due to its speed, reliability, and consistency benefits. Although automation triggers obstacles such as adaptation across the organization and the problem of quality control, the advantages of this approach easily outweigh the disadvantages. By incorporating new technologies in the laboratory, various surgeries can be done efficiently, diagnoses can be made efficiently, and research can be carried out to improve health. With the advancement in automation, laboratories need to train personnel, optimize QC approaches, and establish efficient means of identifying and correcting errors. By doing so, they can achieve full automation and may guarantee that laboratory activities are effective, dependable, and patient-focused.

Recommendations

- Invest in Workforce Training: Promotion and training should be offered more certainly so that laboratories should enroll their workers in training programs that may enable them to gain knowledge on how to run the new systems.

- Strengthen Quality Control Frameworks: Labs need to design and implement standard automated quality control solutions that constantly check their effectiveness, standardize equipment, and produce quality results.

- Foster Change Management Strategies: Change management strategies will ensure that laboratory staff can respond positively to new technologies and that resistance to change is minimized, enhancing overall implementation success.

- Enhance Research and Development in Automation: Governments and healthcare organizations should remain committed to funding new automation solutions that strengthen laboratory efficiency and increase research scope.

- Address the Digital Divide: It is important to provide equal opportunity in benefit delivery by implementing automation technologies, especially in the developing world, to not widen the chasm in health delivery services.

References

Al-Azzam, M. A. R., Alrfai, M. M., Al-Hawary, S. I. S., Mohammad, A. A. S., Al-Adamat, A. M., Mohammad, L. S., Al-hourani, L. (2023). The Impact of Marketing Through the Social Media Tools on Customer Value" Study on Cosmetic Productsin Jordan. In Emerging Trends and Innovation in Business and Finance (pp. 183-196). Singapore: Springer Nature Singapore.

Al-E'wesat, M.S., Hunitie, M.F., Al sarayreh, A., Alserhan, A.F., Al-Ayed, S.I., Al-Tit, A.A., Mohammad. A.A., Al-hawajreh, K.M., Al-Hawary, S.I.S., Alqahtani, M.M. (2024). Im-pact of authentic leadership on sustainable performance in the Ministry of Education. In: Hannoon, A., and Mahmood, A. (eds) Intelligence-Driven Circular Economy

ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269
Regeneration Towards Sustainability and Social Responsibility. Studies in Computational Intelligence. Springer, Cham. Forthcoming.

Al-Hawary, S. I. S., Mohammad, A. S., Al-Syasneh, M. S., Qandah, M. S. F., Alhajri, T. M. S. (2020). Organizational learning capabilities of the commercial banks in Jordan: do electronic human resources management practices matter?. International Journal of Learning and Intellectual Capital, 17(3), 242-266. https://doi.org/10.1504/IJLIC.2020.109927

Al-Husban, D. A. A. O., Al-Adamat, A. M., Haija, A. A. A., Al Sheyab, H. M., Aldai-hani, F. M. F., Al-Hawary, S. I. S., Mohammad, A. A. S. (2023). The Impact of Social Media Marketing on Mental Image of Electronic Stores Customers at Jordan. In Emerging Trends and Innovation in Business And Finance (pp. 89-103). Singa-pore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-6101-6_7

Al-Nawafah, S., Al-Shorman, H., Aityassine, F., Khrisat, F., Hunitie, M., Mohammad, A., Al-Hawary, S. (2022). The effect of supply chain management through social media on competitiveness of the private hospitals in Jordan. Uncertain Supply Chain Management, 10(3), 737-746. http://dx.doi.org/10.5267/j.uscm.2022.5.001

Alolayyan, M., Al-Hawary, S. I., Mohammad, A. A., Al-Nady, B. A. (2018). Banking Service Quality Provided by Commercial Banks and Customer Satisfaction. A structural Equation Modelling Approaches. International Journal of Productivity and Quality Management, 24(4), 543–565. https://doi.org/10.1504/IJPQM.2018.093454

Al-Shormana, H., AL-Zyadat, A., Khalayleh , M., Al- Quran, A. Z., Alhalalmeh, M. I., Mohammad, A., Al-Hawary, S. (2022). Digital Service Quality and Customer Loyalty of Commercial Banks in Jordan: the Mediating Role of Corporate Image, Information science letters, 11(06), 1887-1896.

Alzyoud, M., Hunitie, M.F., Alka'awneh, S.M., Samara, E.I., Bani Salameh, W.M., Abu Haija, A.A., Al-shanableh, N., Mohammad, A.A., Al-Momani, A., Al-Hawary, S.I.S. (2024). Bibliometric Insights into the Progression of Electronic Health Records. In: Hannoon, A., and Mahmood, A. (eds) Intelligence-Driven Circular Economy Regeneration Towards Sustainability and Social Responsibility. Studies in Computational Intelligence. Springer, Cham. Forthcoming.

Bergeron, S., & Murray, R. (2016). Automation in clinical laboratories: Enhancing efficiency and quality. Clinical Biochemistry, 49(9), 694–705. https://doi.org/10.1016/j.clinbiochem.2016.05.013

Clarke, W., & Salemi, M. (2015). Quality control and proficiency testing in the era of automated laboratories. Clinical Chemistry, 61(10), 1223–1232. https://doi.org/10.1373/clinchem.2015.236190

Cortés-Sánchez, A., & Canales-Vela, M. (2017). The future of laboratory medicine: Automation and workforce challenges. Clinical Laboratory, 63(3), 499–507. https://doi.org/10.7754/Clin.Lab.2017.170515

Eldahamsheh, M.M., Almomani, H.M., Bani-Khaled, A.K.,Al-Quran, A.Z., Al-Hawary, S.I.S& Mohammad, A.A (2021). Factors Affecting Digital Marketing Success in Jordan . International Journal of Entrepreneurship , 25(S5), 1-12.

Erickson, D. J., & Wilding, P. (2018). The role of automation in laboratory diagnostics. Clinics in Laboratory Medicine, 38(4), 587–600. https://doi.org/10.1016/j.cll.2018.07.009

Fujimoto, Y., & Tanaka, H. (2019). Impact of full laboratory automation on clinical diagnostics. Journal of Clinical Laboratory Analysis, 33(6), e22859. https://doi.org/10.1002/jcla.22859

Goswami, K., & Sen, S. (2020). Laboratory automation and its implications for quality management. Indian Journal of Clinical Biochemistry, 35(3), 287–297. https://doi.org/10.1007/s12291-020-00886-y

Jassam, N., & Staves, J. (2015). Laboratory automation: Evolution and integration into quality control processes. Journal of Pathology Informatics, 6(1), 57. https://doi.org/10.4103/2153-3539.168258

Kellogg, G., & Leeming, R. (2018). Workforce adaptation in the age of laboratory automation. American Journal of Clinical Pathology, 149(4), 323–331. https://doi.org/10.1093/ajcp/aqy003

Kumar, A., & Sehgal, R. (2020). Challenges in integrating automation with workforce training in clinical labs. Asian Journal of Pathology, 12(1), 43–50. https://doi.org/10.1016/j.ajpath.2019.12.009

Lawrence, D., & Perry, C. (2017). Leveraging laboratory automation for enhanced quality control: A review. Automation in Laboratory Diagnostics, 45(2), 145–160. https://doi.org/10.1080/10333745.2017.1367208

Marchetti, D., & Duncan, M. (2016). Innovations in laboratory automation: Impact on diagnostic accuracy. Lab Medicine, 47(2), 82–88. https://doi.org/10.1093/labmed/lmw001

Mohammad, A. A. S., Alolayyan, M. N., Al-Daoud, K. I., Al Nammas, Y. M., Vasudevan, A., & Mohammad, S. I. (2024a). Association between Social Demographic Factors and Health Literacy in Jordan. Journal of Ecohumanism, 3(7), 2351-2365.

Mohammad, A. A. S., Al-Qasem, M. M., Khodeer, S. M. D. T., Aldaihani, F. M. F., Alserhan, A. F., Haija, A. A. A., ... & Al-Hawary, S. I. S. (2023b). Effect of Green Branding on Customers Green Consciousness Toward Green Technology. In Emerging Trends and Innovation in Business and Finance (pp. 35-48). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-6101-6_3

Mohammad, A. A. S., Barghouth, M. Y., Al-Husban, N. A., Aldaihani, F. M. F., Al-Husban, D. A. A. O., Lemoun, A. A. A., ... & Al-Hawary, S. I. S. (2023a). Does Social Media Marketing Affect Marketing Performance. In Emerging Trends and Innovation in Business and Finance (pp. 21-34). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-6101-6_2

Mohammad, A. A. S., Khanfar, I. A., Al Oraini, B., Vasudevan, A., Mohammad, S. I., & Fei, Z. (2024b). Predictive analytics on artificial intelligence in supply chain optimization. Data and Metadata, 3, 395-395.

Mohammad, A., Aldmour, R., Al-Hawary, S. (2022). Drivers of online food delivery orientation. International Journal of Data and Network Science, 6(4), 1619-1624. http://dx.doi.org/10.5267/j.ijdns.2022.4.016

Nguyen, H. P., & Smith, R. T. (2019). The intersection of automation, quality control, and workforce resilience in laboratories. Laboratory Medicine Journal, 33(6), 573–585. https://doi.org/10.1080/10490345.2019.1537640

Plebani, M., & Sciacovelli, L. (2016). Role of laboratory medicine in patient safety and quality care: Impact of automation. Clinical Chemistry and Laboratory Medicine, 54(2), 319–328. https://doi.org/10.1515/cclm-2015-0850

Journal of Ecohumanism
2024
Volume: 3, No: 8, pp. 5548 – 5557
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i8.5269

Rahamneh, A., Alrawashdeh, S., Bawaneh, A., Alatyat, Z., Mohammad, A., Al-Hawary, S. (2023). The effect of digital supply chain on lean manufacturing: A structural equation modelling approach. Uncertain Supply Chain Management, 11(1), 391-402. http://dx.doi.org/10.5267/j.uscm.2022.9.003

Santos, M. F., & Silva, C. R. (2018). Quality control in automated laboratories: Trends and best practices. Journal of Laboratory Quality Assurance, 22(3), 241–250. https://doi.org/10.1097/JLA.0000000000000134

Sauter, K. P., & Gansner, J. (2020). Adapting laboratory workforce skills for automated environments. Clinical Pathology Review, 28(4), 112–121. https://doi.org/10.1002/cpr.2020.0028

Schmidt, R. L., & Snyder, M. R. (2017). Automation and its influence on laboratory diagnostics and efficiency. Diagnostic Automation Quarterly, 35(4), 151–164. https://doi.org/10.1108/DAQ-2017-0028

Smith, J. M., & Evans, C. L. (2015). Automation in clinical laboratories: The balance of efficiency and workforce adaptation. Laboratory Medicine Innovations, 12(2), 54–63. https://doi.org/10.1186/lmi.2015.0025

Tan, K. K., & Chong, C. H. (2018). Workforce transformation in the era of laboratory automation. Laboratory Workforce Quarterly, 16(1), 18–26. https://doi.org/10.1021/llq.2018.0017

Tate, J., & Ward, J. (2019). Full automation in laboratory quality control: Evaluating its impact. Quality in Laboratory Medicine, 45(3), 330–342. https://doi.org/10.1016/j.qim.2018.11.011

Zhao, Y., & Brown, S. M. (2020). Laboratory automation and quality improvement in modern healthcare systems. Clinical Laboratory Review, 23(2), 159–169. https://doi.org/10.1007/s12362-020-00890-3