SPOTLIGHT feature

LIMS & Lab Automation

Rapid COVID-19 testing enabled by advanced laboratory automation and LIMS

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Over the last decade, laboratory automation has proven to be critical, and its benefits, such as increased throughput, standardisation and reproducibility, have been recognised by organisations worldwide. The importance of automation has especially come to light during the COVID-19 pandemic, where it has enabled laboratories to operate efficiently in a challenging climate. First, it can minimise the number of people required on-site, which helps to reduce transmission risks and overcome the shortage of trained technicians, and second, it facilitates the rapid scale up of diagnostic testing. This article reviews the importance of automation and the role of digital solutions within automated science. It goes on to explore how automated processes featuring laboratory information management systems (LIMS) software have minimised disruption from the pandemic, and allowed COVID-19 testing to be quickly scaled up to meet demand.

Advantages of automation

Automation has many benefits for a laboratory. One of the most widely acknowledged advantages is the ability to achieve high levels of throughput and processing that are not possible with manual methods. However, there are important additional benefits to note, for example, minimising human interaction reduces the risk of errors, resulting in improved data quality, integrity and reproducibility. By reducing the hands-on time needed on basic repetitive tasks, automation also frees scientists up for higher value activities without interruptions. Furthermore, automation provides flexibility for laboratories to scale operations to meet current workflow and future capacity needs.

There are also other advantages of automation that may be initially overlooked. For example, a positive impact of higher throughput and reduced errors means that laboratories can reduce time spent on re-testing samples, and, therefore, shorten research timelines and iteration cycles. Additionally, the higher quality data generated can more easily be used for artificial intelligence (AI) and machine learning (ML) applications to drive further insights.

Automation can take place on any level, from simple tasks to complex systems. Initially used to allow high throughput screening in drug discovery, automation's benefits are now also being recognised in other areas, for example in QA/QC, production environments and precision medicine. It has many applications across different stages of the pharmaceutical industry and most recently, implementation has been rising in diagnostic testing for COVID-19.

Despite its many advantages, one of main barriers to entry for automation, until now, is that it can cause disruption during implementation. However, the benefits outweigh the time and effort for implementation since without automation, discovery and progress can be stifled, and laboratories will not be able to keep up with the competition and continue to meet customer expectations. Laboratories that embraced automation prior to the pandemic have been able to better respond to the challenges posed and return to full productivity more quickly. Indeed, during the COVID-19 pandemic, laboratory automation has increasingly been viewed in a strategic way to assure business continuity.

The importance of digital systems

Automated science is often regarded as being built on three foundational pillars:

1. Physical automation, the hardware that includes tools such as analytical instruments, robotic sample handling and automated reagent supply.

2. Data infrastructure, encompassing laboratory information management systems (LIMS) to manage samples and data, electronic laboratory notebooks (ELNs), dedicated software connectivity tools for bi-directional data transfer, and internet capable devices (internet of things, IoT). Essentially the entire infrastructure that enables the generation of standardisable, sharable data and makes it available for wider use.

3. AI and ML, deep learning technologies that take large volumes of data and turn them into the insights that drive discovery and push the science forward [1,2].

Figure 1: The three pillars of automation.

The complete benefits of laboratory automation are fully realised when combining the three elements above. Here, digitalisation is the critical link between these pillars, with digital tools connecting the physical instruments to the advanced analytical tools. LIMS has a key role to play in collecting, centralising and managing data, automating processes, and delivering connectivity and data integrity to provide a strong foundation for AI and ML. For example, LIMS manage Standard Operating Processes for the analytical instruments and collect large amounts of high-quality experimental and operational data, storing it in a manageable way so that it can be analysed in deep learning.

LIMS software handles data securely and comprehensively to ensure data integrity and traceability, which is crucial for complying with regulations and guaranteeing product/result quality. LIMS can also allow laboratories to automate processes, such as reagent re-stocking or flagging when instrument maintenance may be required. Lab automation specific software solutions, such as Thermo Scientific Momentum workflow software, enable connection to external applications such as LIMS, ELNs and other platforms to streamline data management and tracking. This connectivity also enables users to connect and synchronise applications across multiple different laboratory sites.

Underlying digital transformation is the concept of FAIR data, key in today's laboratory environment. FAIR data is findable, accessible, interoperable and reusable, and it is these key attributes that make it so valuable. This concept goes beyond instruments simply talking to one another. It means data must be findable and accessible between systems and scientists, and be of sufficient quality to be re-used with confidence. Data management through digitalisation supports the achievement of FAIR data.

There is no doubt that digitalisation is key to enabling automated science. The IoT provides tools to generate huge volumes of research data and metadata, including operational, environmental and inventory. Processes are honed and integrity increases as manual steps, such as data transcription, are removed. Integrated physical and digital automation allows facilities to collaborate under standardised conditions. When this is achieved, scientists can obtain reliable high-quality data that can be shared and accessed across different platforms by all who need it, while feeding machine learning applications.

Rising to the challenges of COVID-19

The COVID-19 pandemic has created huge challenges for laboratories worldwide as they have to maintain social-distancing guidelines and maintain continued operation with fewer people on site.

Moreover, there are further challenges for diagnostic laboratories in particular as they face intense pressure for increased capacity and expanded services to accommodate COVID-19 testing. In turn, this has placed additional demands on data management systems as scientists need to increase throughput while tracking the samples' journeys and accurately reporting results.

Laboratories using automated tools have been able to rise to these challenges. A study entitled 'High-speed large-scale automated isolation of SARS-CoV-2 from clinical samples using miniaturised co-culture coupled to high-content screening' [3], has proven that automation is indeed enabling rapid testing with minimal human interaction, which reduces the risk of contamination. The paper describes how scientists developed a new high-throughput isolation strategy using novel technologies for rapid and automated isolation of SARS-CoV-2.

Automation in action

Achieving high throughput workflows and data integrity and traceability are especially important for enabling diagnostic laboratories to scale up services and expand testing capabilities in response to COVID-19. Yet, expanding high throughput testing capabilities without scaling workflows in the digital space can limit the efficiencies automation offers and potentially compromise the integrity of results. During the global pandemic, there are

heightened considerations, especially with regards to developing robust testing systems.

Highly automated molecular diagnostic testing systems, such as the Thermo Fisher Scientific Amplitude solution, have been developed and are capable of analysing up to 8,000 COVID-19 specimens in 24 hours with minimal user interaction. By using new systems such as this, which incorporate all three pillars of automation, including advanced data tracking via LIMS, laboratories can rapidly scale their COVID-19 testing workflows to the high volumes needed. This ultimately helps reduce the spread of disease, and restore economies and communities.

The flexibility automated solutions offer has allowed forward-thinking laboratories to quickly return to near-full productivity, while operating in accordance with social distancing requirements and for protection of their personnel. Remote access to data has also enabled easier collaboration between teams. And, when restrictions are lifted and staff can return, these laboratories will be ideally placed to use their automated workflows to further extend their capabilities.

Continued interest and investment in automation

Laboratory automation has a proven track-record of improving throughput and, ultimately, productivity in laboratories. The COVID-19 pandemic has resulted in a more widespread adoption of automation as laboratory managers acknowledge the immediate need for its benefits, including increased standardisation, reproducibility, and data quality.

Diagnostic laboratories are also recognising the opportunities afforded by automation in terms of scalability and flexibility. Scientists have responded to the many challenges presented by the COVID-19 pandemic by implementing new tools and ways of working. Not only have they been able to rapidly scale up and increase COVID-19 testing volumes; they have been able to minimise on-site user interaction to operate reliably during social distancing restrictions. As growing numbers of laboratories embrace automation, these solutions are poised to increase the pace of analytical testing for years to come.

2020 witnessed a dramatic increase in automation driven by both short-term demand for testing and research in COVID-19, but also continued interest in forward looking projects based on a broader shift to automation driven by business continuity. Companies witnessed how automated laboratories have continued to run more efficiently than manual ones, which has accelerated discussions on how laboratories can fully embrace the significant benefits of digital transformation and automation.

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