White Paper

Transforming Laboratories with Robotics

Part 1: Shaping the Path with Industry Insights

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METTLER TOLEDO

1. Summary

Today's laboratories face growing pressure to deliver faster, more accurate results while also contending with stricter regulations, rising complexity, and chronic skills shortages. Traditional manual workflows are increasingly unable to keep pace with the demands of the modern lab, forcing organizations to look to robotic automation as a potential solution.

This white paper is the first in a series of three from ABB and METTLER TOLEDO drawing from a Voice of the Customer survey of professionals from the pharmaceutical, biopharmaceutical, chemical, and battery development industries. The survey assessed attitudes to the current state of laboratory operations, opportunities, and challenges of successfully implementing automated workflows at scale.

This paper shows the current state of laboratory operations. It identifies the main reasons for robotic automation and highlights the common challenges and issues that slow down adoption.

Key Findings At-a-Glance

Robotic Automation Adoption Is Uneven
Most labs remain in their early stages, focused on repetitive tasks like prep and QC.

Fragmented Systems
Disconnected tools force manual data transfer, causing errors and delays.

QC Leads, R&D Lags
Standardized QC is easier to automate while variable R&D processes is slowing adoption.

Early Progress Shows Promise
Pilots and retrofits show that automating improves speed, reproducibility, and cycles.

Talent Is Underused
Skilled scientists spend too much time on low-value tasks.

Bottlenecks Persist
Manual delays cascade across projects, cutting productivity.

Strategic Integration Is Essential
Phased rollout, interoperability, and leadership drive success.

Future papers will explore opportunities for robotic automation. They will discuss how organizations can create an autonomous, data-rich, and connected "lab of the future." The papers will also cover what to consider when choosing the right partner for this journey.

2. Introduction

Lab testing has changed significantly in recent years. New technologies, evolving markets, and skills shortages are shaping laboratories at an increasing pace. In particular, rising customer demands for faster results and time to market are pushing companies to find ways to do things more quickly, accurately and efficiently, without compromising on safety.

Traditional manual processes are often hard to speed up without sacrificing quality or affecting the integrity of results. Research and development (R&D) is highly complex, while Quality Control (QC) faces increasing demands for accuracy, reproducibility, and throughput. Many processes also involve the handling of potentially dangerous and highly potent substances which compromise the safety of lab workers if not properly handled.

As organizations the world over search for solutions to these challenges, many are increasingly looking to robotics as a potential answer.

New processes are emerging that combine robots with lab instruments to automate, enhance, and optimize critical lab workflows. These systems combine precision-engineered robotic platforms with specialized software, sensors, and modular instrumentation. They can also be optimized for highly specific applications and use cases such as sample preparation, formulation, mixing, analysis, and reporting. Crucially, they achieve these workflows with minimal manual input.

Key Factors Driving The Adoption of Laboratory Robotics

- **Growing complexity:** Advances in materials science, synthetic biology, and chemical engineering are enabling labs to manage more variables, handle and process larger data sets, and speed up iteration cycles.
- **Higher throughput:** In industries like pharmaceuticals and battery development, the rapid screening and testing of candidate compounds or materials is essential to speed up development cycles while remaining competitive.
- **Labor shortages:** Rising retirements and too few new entrants are seeing many labs struggling to fill vacancies. Automation helps close the widening skills gap. It offloads repetitive or precision-sensitive tasks. Offloading repetitive tasks allows existing staff to focus on higher-level research activities that demand more human involvement.
- **Digital transformation:** The move toward “smart labs” and digitalized ecosystems has widespread benefits, but it also needs to be underpinned by effective technologies. Automated data capture, seamless integration with Laboratory Information Management systems (LIMS), and real-time analytics are all fundamental to achieving the lab of the future.
- **Regulatory pressure:** Robotic workflows enhance traceability and consistency, which are critical for meeting regulatory standards, and ensuring the validity of scientific outcomes.

Automating workflows offers substantial benefits. Chief among these benefits is a reduction in human errors. By minimizing manual intervention, robotics reduces the likelihood of mistakes. This helps to improve reproducibility, while also ensuring uniform data quality.

Running processes 24/7 or across several workflows in parallel improves both throughput and scalability. This speeds up testing and development cycles, helping to make better data-based decisions.

Unlocking the vast potential of these opportunities cannot be achieved overnight. Nor are there any 'one-size fits all' solutions. Organizations must consider a wide range of specific factors such as initial capital investment, system interoperability, change management, and the need for customization to fit unique lab environments. Successfully deploying increased workflow automation also requires thoughtful integration with existing processes, proper validation, and a clear understanding of how both human and automated workflows complement each other to the greatest effect.

This white paper is the first in a series of three papers. It comes from ABB Robotics and METTLER TOLEDO. The paper examines major trends and concerns that drive robotic automation in laboratories. It also discusses key available technologies and their benefits. Finally, it explains how to implement strategies effectively to achieve the best outcomes.

2.1. Voice of Customer Project

The contents of this document are based on a targeted global Voice of the Customer survey featuring extensive and detailed interviews with professionals from the pharmaceuticals, biopharmaceutical, chemical, battery development, and electronics industries.

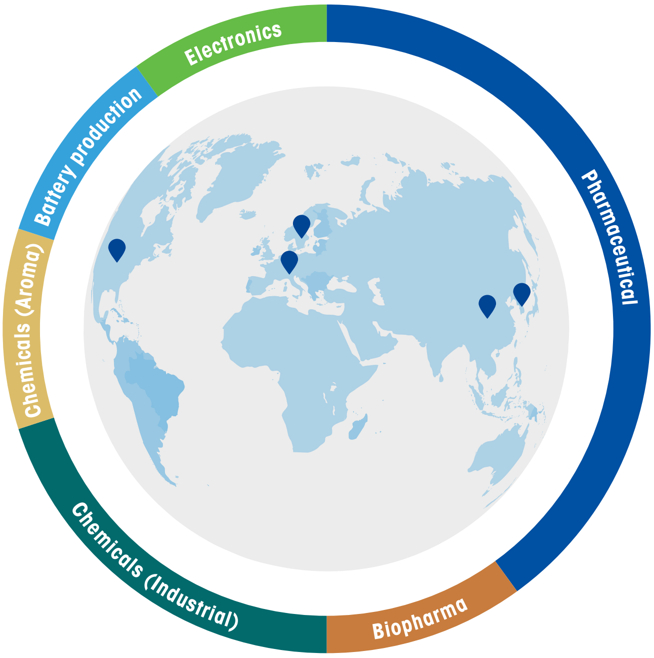
These industries were selected primarily because of their heavy reliance on lab operations to deliver both innovation and regulatory compliance. As such, many are ideal candidates for a greater deployment of robotic technologies. The survey design attempted to ensure a balance of perspectives across different functions, capturing viewpoints from both centralized R&D hubs and QC testing disciplines.

This holistic approach gives us confidence that the conclusions and recommendations presented reflect the real-world needs of organizations working at the cutting edge of science and technology.

Methodology

1-hour interviews with respondents representing QC, R&D, and Testing Services functions

Breakdown of response base by industry:



Countries covered:

- United States
- China
- Switzerland
- Sweden
- South Korea

Industries covered:

- Pharmaceutical
- Biopharmaceutical
- Battery production
- Electronics
- Chemical production

24 questions covering multiple aspects, including:

1. Future vision	The future vision for your lab and where robotics fit in.
2. Current situation in the lab or workplace today	How well does your lab currently run?
3. Current robotic automation levels and opportunities	Could automating workflows help you use your people more effectively?
4. Challenges and barriers to robotics	What challenges do you have with your current processes and what's stopping you from automating them?
5. Short-term plans for tackling challenges	How could automation help you meet your current challenges?
6. Desired features and benefits	What do you look for when it comes to robotic assisted workflows?
7. Implementation	Addressing concerns and getting what you want from automated processes.
8. Decision-making process	How do you decide on the best supplier and who makes the decisions?
9. Decision factors	How important are cost, reputation and integration when deciding?
10. Return on Investment	How do you measure the Return on Investment (ROI) of lab equipment and robotics?
11. Staying up to date	How do you keep up to date on laboratory trends and innovation?

3. Current State of Robotic Laboratory Automation

"It's not that we don't want to automate. Most of us are desperate to, but until we can, we're stuck doing things by hand that really should have been automated years ago."

Many in the field share a common vision for fully autonomous, digitally integrated labs. However, survey respondents showed a more uneven picture relating to how they currently deploy automation in their lab applications. The survey showed that most labs remain in the early stages of robotic automation, with notable variations across and within different industries.

3.1. A Snapshot of Current Adoption

The survey revealed important findings. In many cases, current automation efforts focus on specific, repetitive manual tasks. These tasks include liquid handling, sample preparation, and simple analytical routines. They do not focus on integrated workflows from start to finish.

Often, automation is applied selectively in areas where throughput and precision are of critical importance, while more complex or interpretive tasks remain manual.

Some labs have advanced further. One reported a pilot-scale, fully automated workflow in a high-throughput lab setting, demonstrating how significant progress can be achieved with the right infrastructure and strategic support. However, such cases currently tend to be the exception rather than the norm.

3.2. Robotic Reach and Limitations

Currently, automation is most-commonly deployed in QC, sample management, and specific formulation or testing steps. More complex applications such as material synthesis, advanced analytics, and experimental design remain largely manual. Adding robotics in R&D environments is often more challenging than in QC, due to their unpredictability and the greater need for flexibility.

As one contributor noted, "Automation is more advanced in QC than R&D, because the processes are more stable and easier to standardize." From this and other similar responses, we conclude that automation gains traction faster where processes are well-defined and outcomes are tightly controlled .

Crucially, the benefits of robotic automation also help to speed up the various processes involved in developing and bringing new products to market. In the words of one respondent, "Automated systems generate more data in a short time than was possible over the past decade. By combining this with the enhanced speed delivered by automated processes, we can now accelerate idea-to-experiment cycles at the research and development stage, and test and validate concepts faster."

3.3. Early Progress and Standardization

Nevertheless, early signs of progress are evident. Several organizations are developing automation, and robotic automation, strategies. They prioritize modularity and interoperability. These organizations recognize the importance of standardization. Standardization helps to deploy robotic workflows to the repeatable parts of research environments.

There is also growing recognition that robotics does not necessarily require complete redesign. "Facilities can be adapted; we just need to plan around constraints," one participant observed, highlighting a shift toward retrofitting and phased integration. In contrast, some are beginning to plan robotics-ready lab spaces, with connectivity, scalability, and accessibility for both robotics and scientists in mind.

Best practice procedures are also evolving. Respondents mentioned testing systems in parallel or during off-hours to avoid disrupting core operations and using lighthouse project or pilot phases to allow new systems to be validated before scaling.

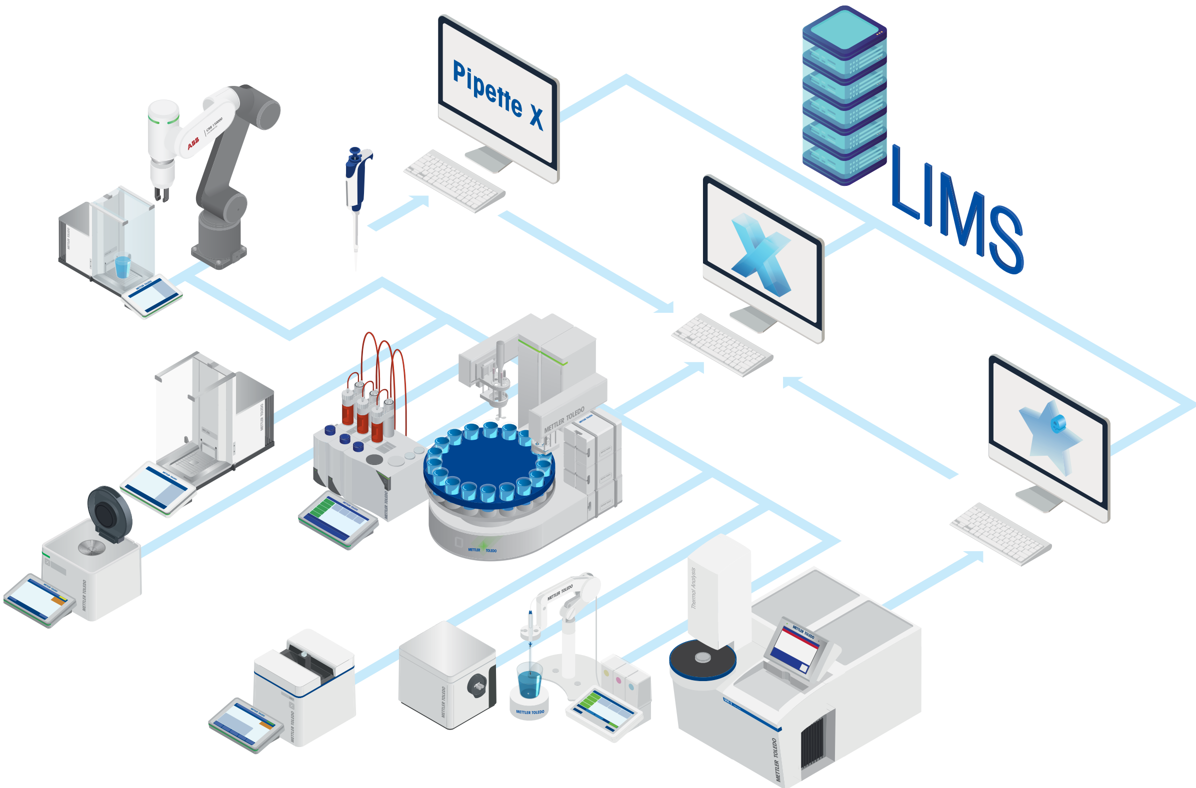


Figure 1: An example of a digitized laboratory ecosystem.

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4. Key Challenges and Focus Areas

"We still rely on a person to carry samples from one bench to another, and another to stitch together the results."

While the benefits of automation are broadly recognized, many labs continue to face day-to-day inefficiencies that put a strain on their time, talent, and resources.

Too many scientists and technicians are still spending too much time on low-complexity activities that could be automated.

"Highly skilled scientists are spending hours doing basic prep work, chasing equipment availability, or reformatting data just to get through the workflow. That's not what we hired them for."

This is echoed by other respondents: "It's not that we don't want to automate. Most of us are desperate to, but until we can, we're stuck doing things by hand that really should have been automated years ago."

Aside from wasting skills that could be deployed more effectively within the lab, having staff stuck on carrying out repetitive tasks also increases the potential for human error. Mistakes arising from inattention, boredom, or fatigue may not be immediately obvious and can propagate through the workflow, resulting in out of specification (OOS) results, or flawed data which can then feed into flawed decision-making. "We sometimes don't catch mistakes until several steps down the line, when we realize something's gone wrong and we have to start again. It's frustrating and costly," said one interviewee.

The linear nature of many manual workflows also increases the risk of bottlenecks. A single delay such as late sample preparation or instrument calibration can potentially hold up an entire day's work, forcing teams to reschedule planned experiments, or reallocate their time to other tasks. The impact of these interruptions cascades, delaying not just individual experiments, but entire projects or development cycles.

Several professionals shared examples of delays in delivering critical analyses due to backlogs in sample preparation or resource bottlenecks. Others pointed to situations in which their teams had been forced to compromise on experimental design because there was not enough capacity available to support more complex protocols.

For teams that frequently work to tight deadlines, these delays often result directly in lost productivity and increased operational risks.

Manual processing can also lead to variations in the quality of data. In situations where different individuals execute procedures with varying levels of experience and expertise, even minor variations in technique or interpretation can lead to inconsistencies. This variability can undermine confidence in results and makes it more difficult to establish standardized workflows. This is particularly the case in environments that rely on strict regulatory compliance, or where there is a need to transfer knowledge frequently between global teams. Without automation to enforce consistency, delivering reproducible results is challenging.

Even advanced automated systems can pose challenges if systems aren't properly integrated. Many labs operate with a mix of hardware and software platforms. These platforms were never designed to work together or to communicate with each other. Data must be manually extracted, reformatted, and uploaded across systems, wasting time and increasing the likelihood of transcription errors.

This inherent fragmentation makes it difficult for labs to build streamlined workflows and hampers their efforts to scale. One respondent observed that their lab had "state-of-the-art instruments that can do incredible things, but no way to connect them in a meaningful process. So, we still rely on a person to carry samples from one bench to another, and another to stitch together the results."

When combined, these issues have an operational and strategic impact that highlights the hidden cost of manual workflows. Labs that continue to rely upon outdated, manual processes will increasingly fall behind, lacking the infrastructure to deliver faster, more reliable results, scale their efforts or redirect staff toward innovation.

> "The way we work today might have made sense 20 years ago.
> But it doesn't work anymore, especially if we want to grow, compete,
> and innovate."

Key Takeaway

Everyday friction, wasted talent, and fragmented systems highlight robotic automation's future role in unlocking lab potential and laying the foundations for growth.

When done well, adding robotic automation speeds up innovation. It helps laboratories follow rules. It allows skilled workers to focus on more important tasks. This approach enables laboratories to deliver results faster and more reliably. They can also remain competitive.

To achieve this, organizations should look to streamline processes, expand automation beyond basic instrumentation, integrate data solutions, and simplify reporting. Retrofitting existing labs with modular, interoperable systems, and designing new ones with scalability in mind enables progress without major disruption.

5. Navigating Adoption Challenges

"When you introduce automation, some see it as losing control, not gaining capability."

While the long-term rewards of robotic lab automation are clear, there are often many obstacles to overcome before they can be realized. Conversations with the survey respondents revealed three overarching categories: cultural and organizational resistance, technical limitations, and financial or strategic hesitation.

5.1. Cultural and Organizational Resistance

Respondents repeatedly mentioned that they manage change from both cultural and operational perspectives.

Many lab workers are understandably concerned by the ability of robots to outperform and/or replace them, carrying out certain tasks faster, more accurately, and more consistently, without stopping or needing a break.

Some professionals also expressed concern that robotics could displace roles or devalue traditional expertise. In many labs, teams have relied on long-established methods and manual routines. Therefore, any disruption to the conventional ways of working, however well intended, is often met with skepticism, discomfort, or push-back both by workers and, sometimes, unions.

"Mindset is one of the biggest obstacles. People are used to being in control of every step. When you introduce automation, some see it as losing control, not gaining capability."

Also, robotics are often misunderstood at the ground level. People widely associate it with full-scale robotics, or assume it applies only to high-throughput industrial environments. In such cases, staff may be unaware of smaller, incremental forms of collaborative robotics that can ease workloads without dramatically altering their roles.

"Some team members were unaware that the tools they were already using were part of a broader automation initiative. Once they realized it was there to help and not replace them, their attitudes changed."

In these cases, the challenge is not just introducing a new system but also managing change. Some respondents use a technique to gain staff buy-in for robotics. They start with small lighthouse projects that have a high impact. These projects directly benefit human workers by, for example, automating repetitive tasks such as sample preparation. Such "lighthouse" projects help to demonstrate value quickly and can also be instrumental in gaining wider acceptance and building momentum generally. "I started small with impactful projects. When people saw real benefits, such as more time for analysis and fewer mistakes, they became much more engaged," said one contributor.

5.2. Technical limitations and Integration Barriers

In situations where lab operators are operating a patchwork of instruments, data systems, and software platforms, such barriers can constrain capabilities, particularly if personnel have little or no knowledge of using robots. This will then limit the ability of operators to create seamless, automated workflows.

In brownfield sites especially, lab facilities were not designed with either robotics or automation in mind, and lack physical space, environmental controls, or connectivity to accommodate robotic systems or cloud-based platforms. Legacy instruments used in those labs may still deliver reliable results, but offer no APIs (Application Programming Interfaces), digital outputs, or remote monitoring capabilities, making them incompatible with many modern robotic frameworks. This incompatibility leaves teams with a choice between expensive upgrades or time-consuming workarounds.

The complexity of integrating automation with legacy systems remains one of the most significant technical barriers facing the industry. Organizations often lack connectivity tools to enable data to flow between systems. "Integration is the hardest part," said one respondent. "Different platforms use different languages, and there's no common data layer. You either have to build something custom or rely on manual handoffs." In such environments, while automating a single task may be achievable, automating an entire workflow often requires substantial IT support, third-party tools, or even replacement systems, increasing the levels of complexity and risk.

Organizations that are successfully moving towards robotic workflows often use a modular approach. They identify areas of the lab that are ready for automation now. At the same time, they plan infrastructure updates that allow for future scalability.

5.3. Financial Constraints and Strategic Uncertainty

Securing the investment needed for both purchasing and implementing robotic workflows can be a significant barrier to adoption, especially for organizations operating with limited budgets or short planning cycles.

As such, securing buy-in from decision-makers can often hinge on the ability to explain, and if possible, quantify potential returns up-front. This can be difficult to do, particularly in R&D and early-stage environments where automation delivers quality, reproducibility, or innovation, rather than immediate tangible cost savings. One respondent noted, "It's not that leadership doesn't see the value. They do. But it's hard to put a number on it until you've already made the investment. That makes it hard to justify."

Figure 2: A cobot working with multiple instruments in a single workflow.

The lack of organizational alignment complicates the situation. There may be no centralized robotic automation strategy. This situation leaves individual teams or departments to advocate for projects independently. A fragmented approach can make it harder to secure funding, coordinate efforts, or achieve interoperability across systems. One participant explained that while there was interest in automation at multiple levels of the organization, "there wasn't a clear owner for it, so nothing moved forward in a coordinated way."

Strategically, robotic automation is also often in competition with other priorities that may be seen as having greater urgency or importance. Some organizations are therefore beginning to embed automation into wider strategic roadmaps, reframing it as a foundational capability that supports multiple business outcomes, and tying it to goals around scalability, digital maturity, and operational resilience.

6. Overcoming the Barriers

While these challenges are significant, they are not insurmountable. Our research highlights that successful implementation is as much about people and planning as it is about hardware and software. Change management, internal education, and cross-functional coordination are essential to overcome resistance. Technical integration must be approached pragmatically, with modular planning and future-proof infrastructure. Financial and strategic alignment fundamentally requires leadership and a long-term vision.

Key Takeaway

Defining the right automated solution and understanding how to articulate its benefits clearly to management is of key importance in getting buy-in from all stakeholders.

Clear communication is also essential when rolling out the solution to users. Transparent communication, inclusivity, and leadership support are all key tools for overcoming resistance. Starting small and demonstrating the direct benefits can often be the best way to win acceptance from skeptical or reluctant staff.

Ultimately, labs that treat robotic automation not merely as a tool but as a transformational initiative that encompasses culture, infrastructure, and business strategy, will be in the best position to lead the next era of scientific innovation.

7. Conclusion - Laying the Foundations

While robotic lab automation adoption is advancing, its progress remains uneven and constrained by fragmented systems, underused talent, and cultural or technical barriers. Yet the benefits are clear. Robotics, when properly planned and executed, has the potential to deliver faster cycles, more reproducible data, and the ability to free skilled scientists to focus on higher-value work. Early adopters have demonstrated that with phased implementation, modular solutions, and strong leadership, automation can transform workflows without major disruption.

This first paper has outlined the current drivers and barriers affecting robotic lab automation. The next paper in this series will look ahead, exploring how organizations can move beyond incremental gains to realize autonomous, data-rich, and seamlessly connected "labs of the future."

Figure 3: A broad portfolio of robot-compatible instruments from METTLER TOLEDO.

8. Glossary of Acronyms and Terminology

Term/Acronym	Definition	Short Description
VoC	Voice of Customer	Direct input/feedback from customers or end users
Lab report	Analytical documentation for laboratory work	Record of lab procedures, results, and analysis
KPI	Key Performance Indicator	Quantitative measure of performance against goals
NPS	Net Promoter Score	Customer loyalty metric: measures willingness to recommend
Stakeholder	Individual/group affected by the project	Anyone with interest or influence in a project
Gap analysis	Comparison of actual vs. desired performance	Identifies differences between current and ideal states
Root cause	Fundamental reason for a problem	Primary source of an issue needing resolution
Workflow	Sequence of processes in lab operations	Ordered steps in lab operations
Action plan	Strategic steps for addressing issues	Outline of required activities for improvement
Sample throughput	Number of samples processed in a time period	Measures lab processing capacity/speed
QC	Quality Control	Lab function ensuring accuracy and reliability
SLA	Service Level Agreement	Contractual commitment on service standards
Metrics	Measurable indicators for assessment	Values tracked for performance/quality monitoring
Pain point	Specific challenge or difficulty encountered	Issue causing operational inefficiency or dissatisfaction
Lighthouse project	A flagship or pilot	A showcase project intended to lead or inspire broader change, new approaches or technologies
LIMS	Laboratory Information Management System	Digital system for managing lab data, workflows, and samples
ELM	Electronic Lab Manual	Digital version of manual lab record keeping
ENB	Electronic Notebook	Digital notebook for recording lab observations and data.
LES	Lab Execution System	Software system for managing, guiding, and documenting lab procedures and workflows to ensure compliance and reproducibility

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