The End of Trial-and-Error Experiments as a Competitive Advantage

Experimentation has long followed a rigid and time-consuming sequence. Change one variable, observe the effect and repeat.

No longer. Modern experimentation methods deliver unprecedented benefits: accelerated time to market, richer decision-making insights and optimized products that outperform anything created with traditional methods.

Experimentation methodology has evolved significantly in the past few decades, but for all the value these methods create, they are woefully underused. Technologists can map complex relationships, uncover hidden interactions and make data-informed decisions with an efficiency unimaginable in the past.

The approach allows technologists to embrace complexity, simultaneously varying many factors to save time and resources. Experimentation cycles are shorter, and insights are richer while significantly reducing time to market.

By strategically varying multiple factors simultaneously, researchers uncover complex interactions driving outcomes. This data-centric approach allows for rapid optimization of processes, products and services, fueling accelerated innovation that addresses evolving market needs.

Design of experiments (DOE) is a proactive methodology for understanding how changing various factors can affect an outcome. Instead of trial and error, DOE lets technologists plan experiments that reveal the effect of many factors and the way that multiple factors interact to influence the result. Sometimes the interaction of two factors is *synergistic*, and the overall effect is greater than the sum of the individual factor effects. Sometimes the interaction is *antagonistic*, and the overall effect is less than the sum of the individual factor effects. This knowledge is crucial for making informed decisions, optimizing processes and driving innovation.

Tom Donnelly, principal systems engineer with JMP, brings decades of expertise in designed experimentation. At JMP, he helps organizations across various sectors understand the complexities of their systems so they can translate data-driven insights into tangible improvements.

Modern scientific discoveries arise from powerful collaborations. Brilliant ideas need advanced tools to make them a reality. “We still have to have the human part. It’s critical, because that’s where the innovative ideas we will test come from. Someone has to propose some new ingredient or catalyst to a formulation to improve yield, for example. Software and textbook experimental designs will not come up with new concepts to test, but these designs will efficiently validate whether or not the idea is any good,” Donnelly said.

“There are methods they employ to take those ideas and test them more rapidly. So the human part of it is still its creative and innovative side, and the methods are just efficient tools. Think of it this way: We used to have a handsaw, and now we have a power saw. We can do it quicker and get a cleaner cut,” he explained.

DOE offers a competitive edge to identify potential breakthroughs, proactively personalize treatments and technologies, and shape emerging trends in the industry. “It’s a methodology where you try to figure out the best place to make the fewest experiments so that you get the most information out of the least amount of data. And so, from an adaptability point of view, you can build your model on things you can do or if you have a lot of historical data,” Donnelly explained.

High-throughput screening, laboratory automation and sophisticated statistical tools facilitate generating robust datasets quickly. Coupled with machine learning algorithms, technologists can make unprecedentedly informed decisions.

“From the beginning, we were able to quantify how much value DOE adds for us. We were using DOE in several internal cases and we were able to actually quantify our savings of at least **50%** of the time and resources. In some cases it was even **70%**.”

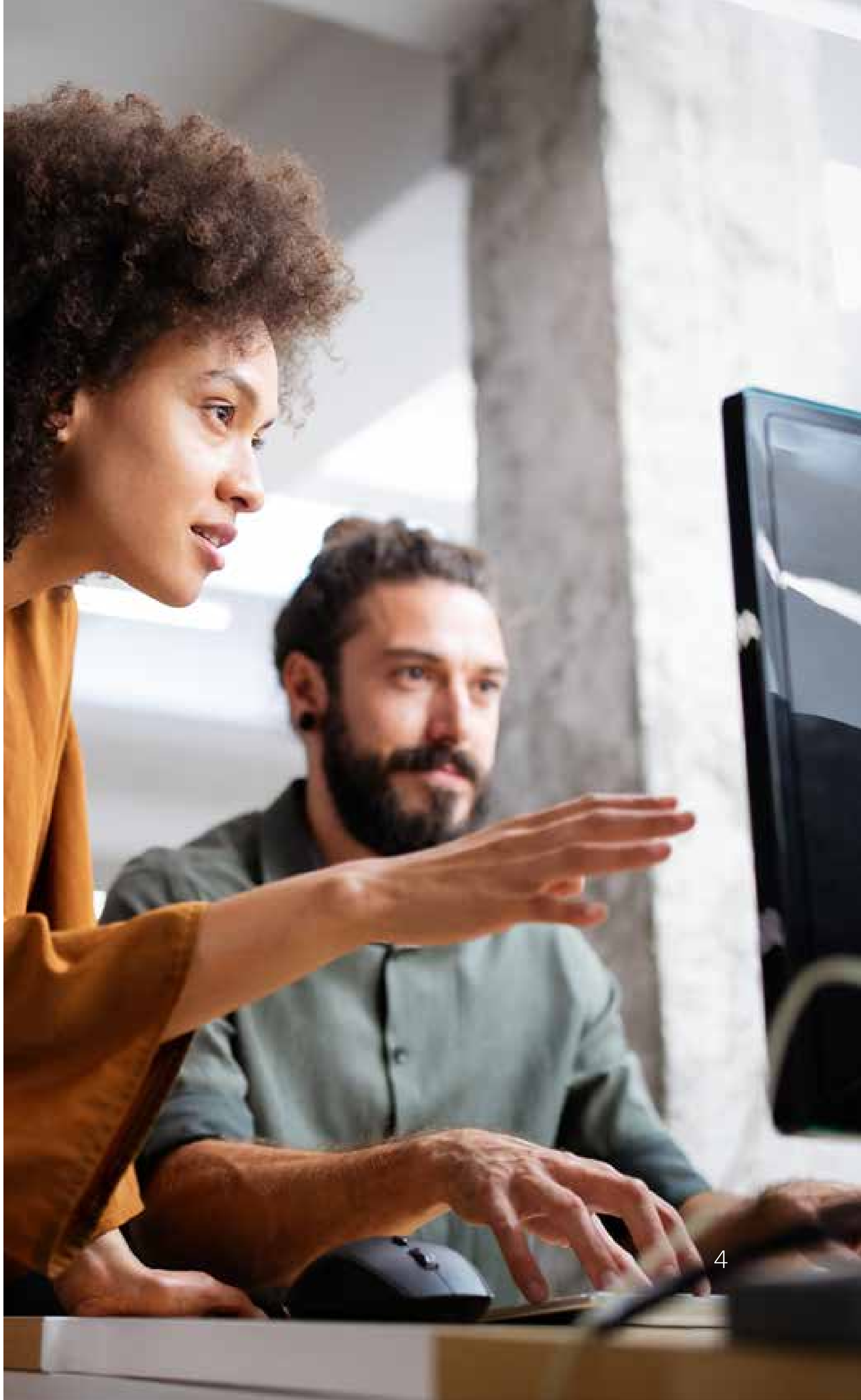
Pilar Gomez Jimenez
Principal Scientist, Johnson Matthey

Illuminating the unknowns and challenging biases

Well-designed experiments work like powerful searchlights, uncovering areas researchers might not even know they need to explore. Technologists risk being influenced by their limited experience or preconceived notions without a structured approach.

Even the most well-intentioned experts can fall prey to unconscious biases, built-in mental shortcuts that subtly influence perception without awareness. Designed experiments introduce a level of objectivity, forcing technologists to consider factors and their possible interactions with one another outside their usual lines of thinking.

Designed experiments provide a structured way to chart the entire multidimensional space in which a technology operates. Instead of just testing isolated changes, DOE unveils how multiple variables interact with one another. This mapping produces a rich understanding of the landscape, ensuring gaps in knowledge are minimized and critical factors aren't left in the shadows.



> “And sometimes, people will just try to shrink the problem, thinking, we can’t do 20 variables, so let’s pick the best three. Well, you’re leaving an awful lot of unexplored territory out there. And so there are methods to look at tens of variables simultaneously and efficiently to cut that list down to the critical few.”

Tom Donnelly
Principal systems engineer with JMP

“The key that most engineers and scientists are searching for is the ability to predict a process; that’s when they start to understand it. And so, when you have many variables, the number of combinations can be astronomical. And it’s like, where to begin in this large space? And sometimes, people will just try to shrink the problem, thinking, we can’t do 20 variables, so let’s pick the best three. Well, you’re leaving an awful lot of unexplored territory out there. And so there are methods to look at tens of variables simultaneously and efficiently to cut that list down to the critical few,” Donnelly said.

This heightened awareness enables technologists to identify potential drawbacks early and make calculated adjustments. It can also reveal surprising capabilities in the technology, facilitating innovative applications.

Looking at where the model breaks down is critical. Zeroing in on weak points prevents wasting time and resources on gathering data that won’t significantly improve results. This breakdown analysis drives laser-focused experimentation. “There are sequential experimental methods, where you start with a sparse set of test trials that may not give you that great of a prediction. Still, you can then augment the first round of test trials with additional runs and move the experimental region into the areas where things are improving,” Donnelly explained.

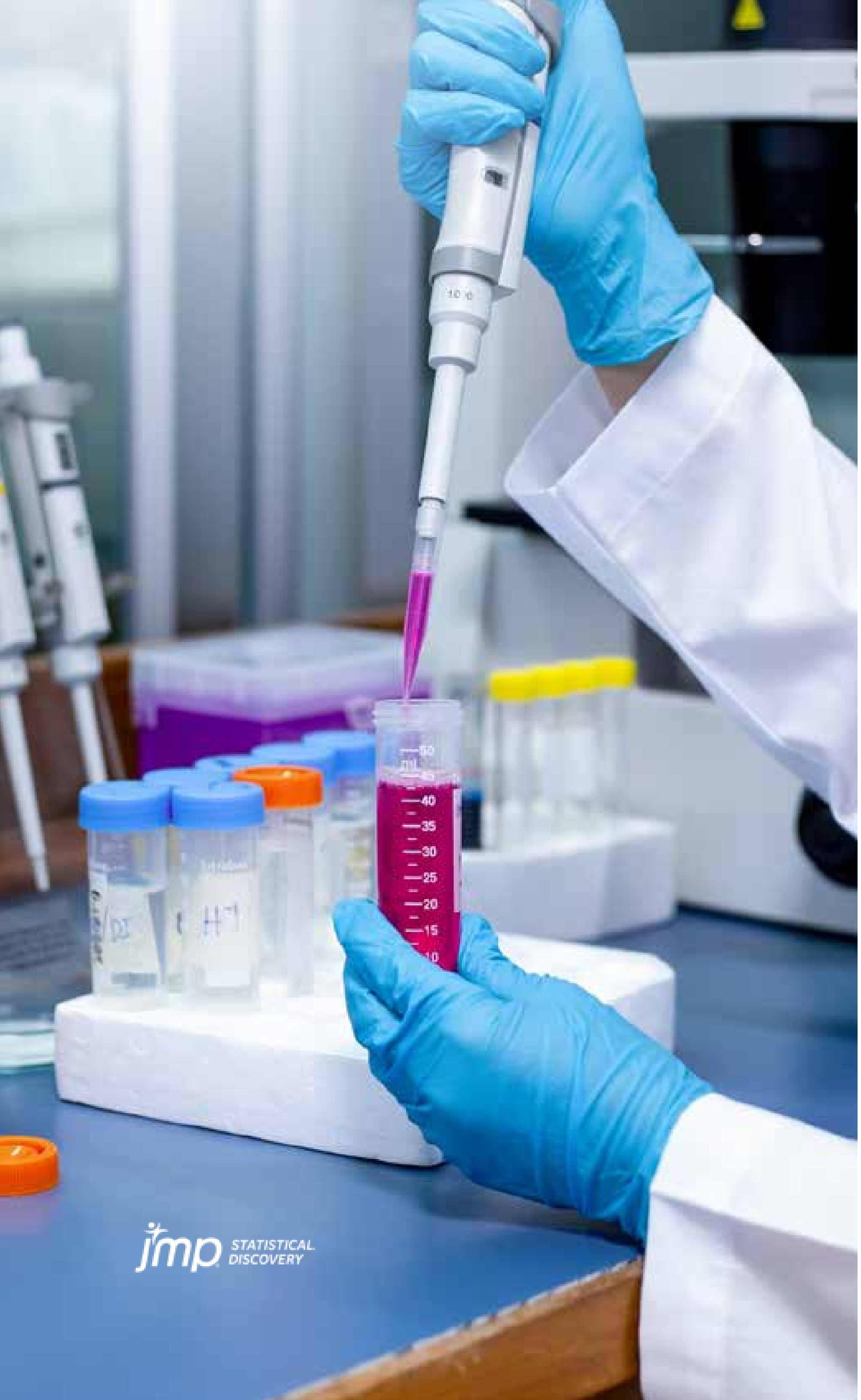
Equipped with more profound knowledge, researchers can make informed decisions about their process and even optimize it. They can find ingenious solutions that otherwise would have been elusive.

The marvels of modern experimentation

At its best, smarter and more modern experimentation drives breakthrough decision-making. It allows technologists to easily explore scenarios by asking “what-if” questions, such as, what process modifications will be needed if costs rise or performance targets change? This dynamic exploration reveals the optimal balance between cost and performance, empowering better-informed management choices.

The power to simultaneously vary multiple factors is game-changing. Instead of one-at-a-time testing, researchers map how numerous variables interact. It reveals complex relationships, helping isolate the factors with disproportionate effect and eliminating those that are insignificant. Resources and time are focused only where they offer the most value.

DOE is the mastermind here. It uses statistical principles to determine the most informative combination of experimental runs,



which slashes trial and error to deliver the maximum insight from a minimum number of experiments. The result is more knowledge in a tighter time frame.

Precision suffers when experiments aren't carefully controlled. DOE helps identify and manage sources of experimental noise or "hidden" factors that undermine accurate results. By understanding these sources of variability, technologists can mitigate their effect, improving the reliability and repeatability of results.

Understanding the underlying science or engineering principles is crucial. Without it, experiments risk being meaningless — narrow ranges might miss effects, while overly broad ranges could prove unusable. For example, in studying temperature, too narrow of a range won't show any effect, and too wide will go from ineffective to outright destructive.

With modern tools, setting up experiments is fast and easy. But those tools won't help if your research questions are fundamentally flawed. Science/engineering knowledge helps frame meaningful experiments that will likely provide useful answers and move your project forward.

"Experimental design methods will only work if the science underneath it works. You can't blindly take these methods out of a book and apply them to a process you don't understand," Donnelly explained.

Many outcomes depend on multiple factors acting in concert, not isolation. DOE excels at disentangling these interactions. A linear experiment would miss an interaction if changing factor A only matters when factor B is at a certain level. Smart experimentation reveals synergies or trade-offs that directly optimize processes and products. In this regard, today's DOE is a powerful ally. It helps define the "working zone" based on your knowledge and then permits you to explore it strategically. This systematic approach enables you to find the optimal settings efficiently, leading to breakthroughs in what's possible.

The methodology hinges on robust data analysis. Insights can go beyond fundamental trends. Statistical models uncover deep patterns and predict outcomes without running every conceivable experiment. Decisions on next steps and optimization become grounded in evidence, reducing costly guesswork.

Experimentation becomes a cyclical learning process. Optimal experimentation is dynamic, not static. Insights inform and refine future experiment designs. Every data point builds a sharper picture. This continuous refinement accelerates improvement and ensures resources are always invested strategically.

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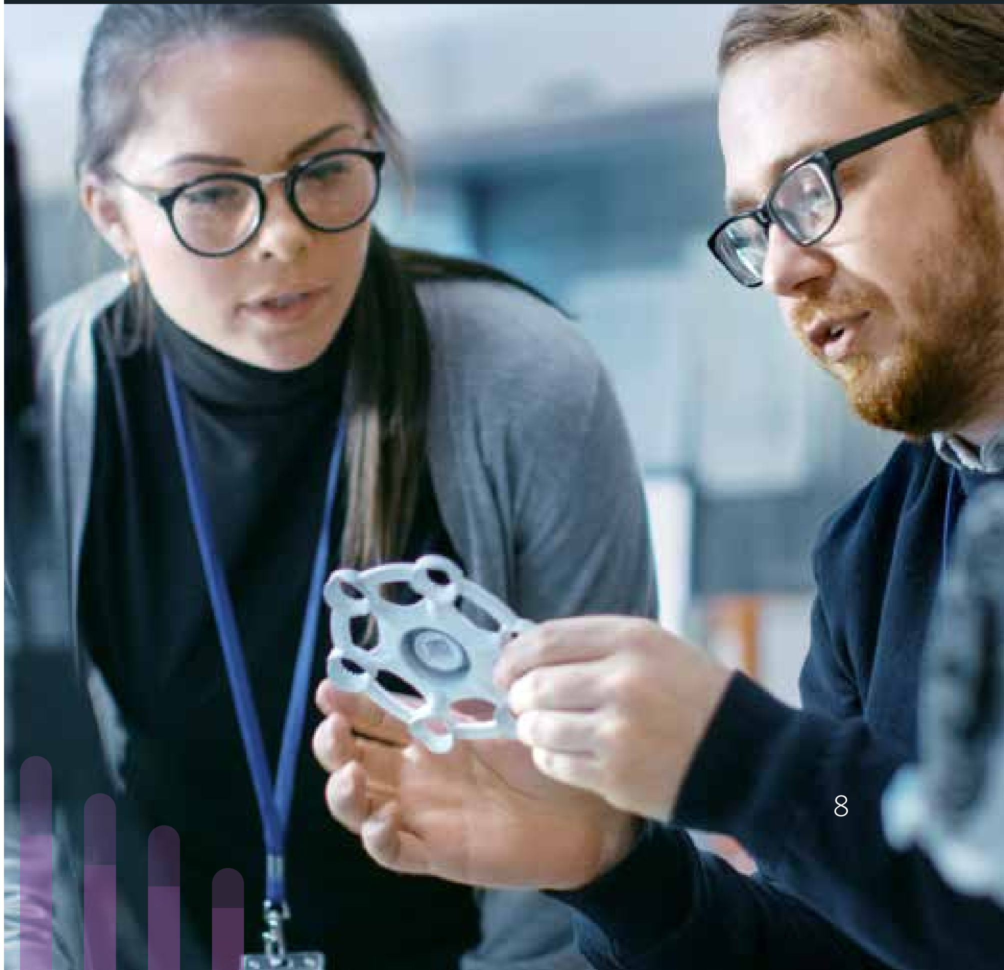


DOE gives access to needed data

DOE helps technologists avoid being misled by "tunnel vision" during development by ensuring focus stays on the multidimensional data essential for making decisions. It identifies the variables that truly matter while preventing distractions of meaningless data noise.

The right visuals convey complex interactions quickly, empowering teams to spot significant trends or anomalies. Also, DOE-generated data demands insightful visualization, not just making it "pretty."

Research isn't done in isolation. Visualization tools make DOE data accessible across discovery, development and manufacturing. Collaboration gets stronger as the same high-quality insights drive decisions.

"In pharma, when people are trying to develop drugs, how many different materials, chemicals and things can be blended together? If you can look at lots of them efficiently to thin that down, you'll move a product to market faster," Donnelly explained.

Visualizing how complex variable sets combine to deliver specific outcomes allows researchers to recognize subtle patterns faster. It fuels hypothesis generation and guides the next rounds of experimental design.

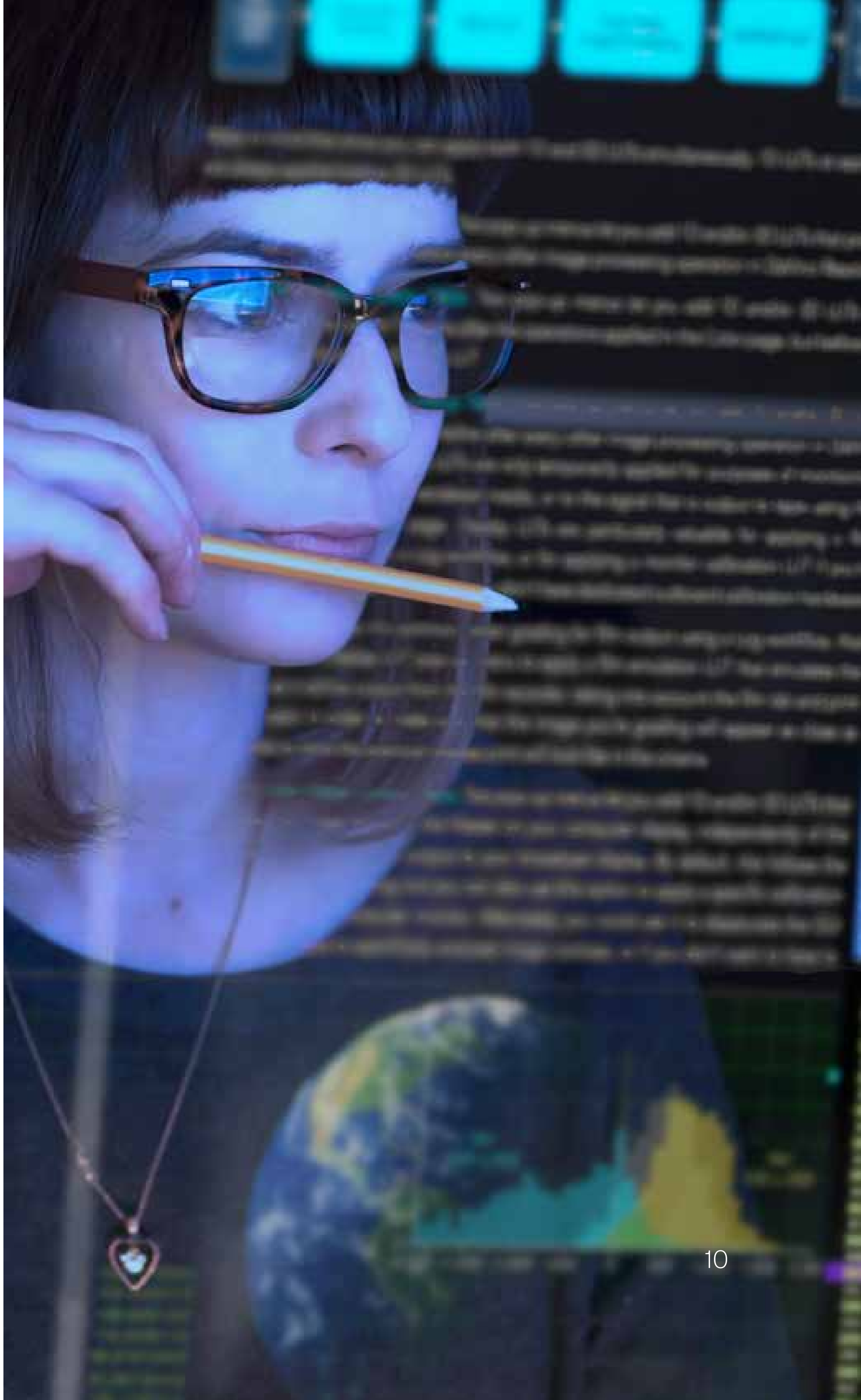
The bane of information overload

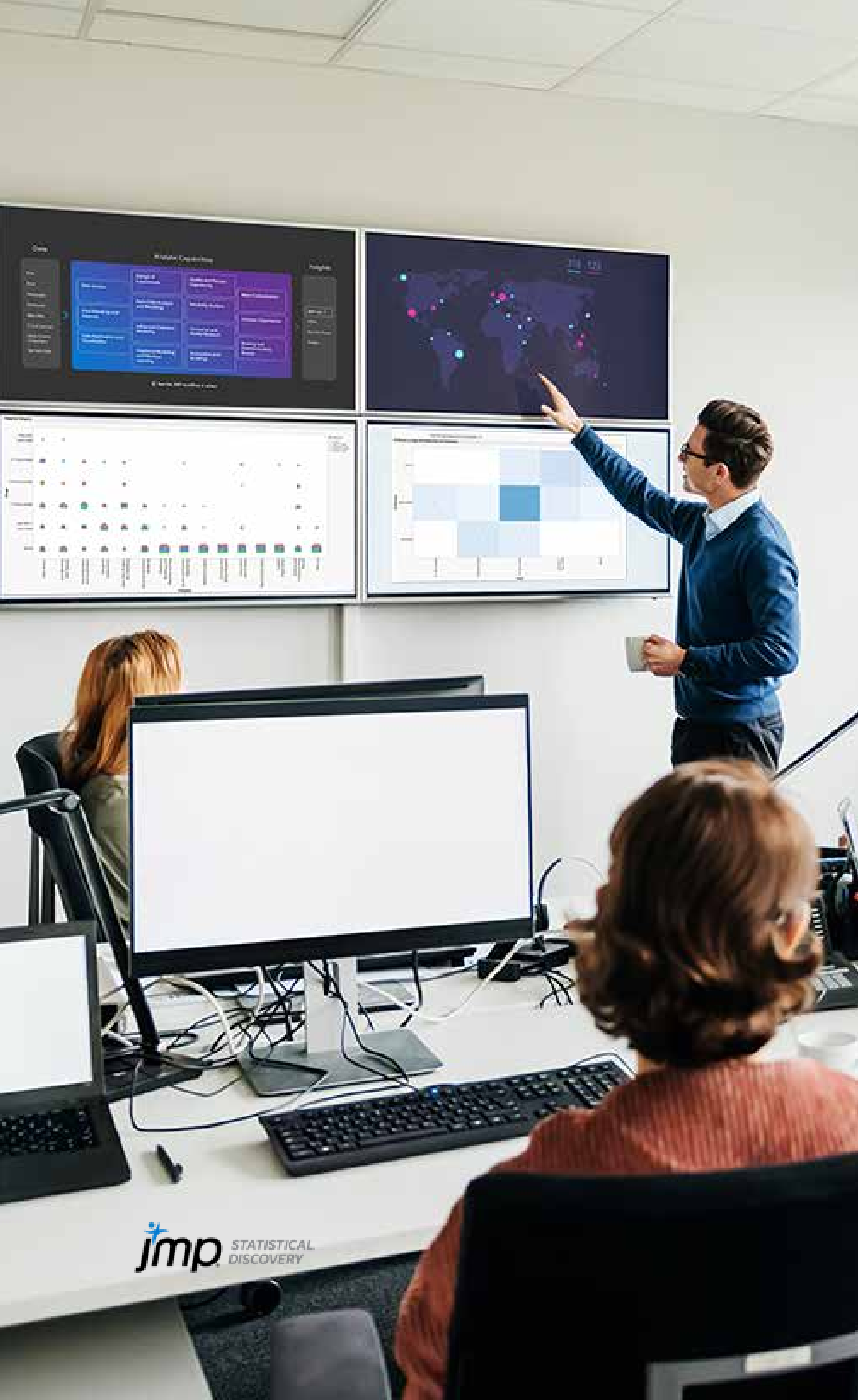
In fields such as drug development or materials science, the potential number of variables and permutations can be overwhelming. Without intelligent tools, the sheer volume of information can impede progress rather than propel it.

DOE brings order to this chaos. It enables tailored, dynamic data visualization beyond just creating charts and graphs to reveal how variables interact. Technologists can visually examine how changing one factor influences not only the responses of interest but also the potential effect of all other factors so they can see potential synergies or hidden problems that linear data obscures.

With DOE, visualizations highlight significant patterns, trends and key inflection points. Outliers, threshold effects and optimal zones become immediately evident.

Visualizations become multilayered. Technologists can zoom out for a comprehensive picture of the entire experimental space and then drill down into specific interactions or data clusters. This big-picture-to-minute-detail flexibility is powerful for analysis.





Moving from exploration to precise results

DOE-powered visualization becomes a tool for precision targeting — it allows technologists to invest resources in future experiments effectively. Time isn't wasted on factors that yield little insight.

Visualizations can track experimental progress. They foster continuous learning and refinement of future research, accelerating optimization.

DOE data, paired with clear visualizations, can validate or challenge the researcher's hypotheses; seeing unexpected patterns can reveal unforeseen possibilities for innovation.

Visualizations don't exist in a vacuum. Teams with diverse expertise — chemists, biologists or engineers — can visually analyze the same DOE data.

Building shared understanding fuels cross-disciplinary collaboration and speeds up breakthroughs. In the near future, expect highly adaptable DOE to drive progress in fields ranging from medicine to renewable energy.

About JMP®

JMP is powerful statistical software designed with scientists and engineers in mind, but ideal for anyone solving problems with data. Packed with tools for data preparation, analysis, graphing, and so much more, JMP has everything you and your organization need to be truly unstoppable with data.

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