The Lean English Podcast

Episode 3: Six Sigma

1. Episode 3: Six Sigma

Welcome to the third episode of the Lean English Podcast. My name is Tom, and I will be your host. Thank you for joining me.

I know there are many other podcasts that you can listen to, so, I thank you for spending your time with me today. If you haven't listened to the first two episodes, I have a question for you: What are you doing with your life? What, are you too good to listen to them? You have better things to do, is that it? You and I both know that's not true. Stop kidding yourself. And I have heard all the excuses about playing with your kids, spending time with your spouse, donating to charity and planting trees to help the environment. Trust me, it's all overrated. I paid thousands of dollars and worked for years to learn what I am going to give to you for free. You could at least listen to the first two episodes. Out of respect. Out of boredom. Out of fear, I don't care. But if you didn't, here's the recap.

Commented [TS1]: I am joking of course.

2. My podcast is designed for the intermediate level English speaker who wants to also learn how to improve their business. You might be a manager who needs help solving problems, or someone who wants to advance their career and needs to acquire some new skills. If you are new to process improvement methodologies, you might not know where to start. The podcast starts at a high-level review of Lean, Six Sigma and Agile to help you choose which method is best. We will then cover more specific tools and techniques so you can feel confident when you decide to implement changes in your organization.

In the first episode of The Lean English Podcast, I laid out the differences between these methods. Lean is the least complex to understand; easiest to implement, and quickest to show benefit. Six Sigma has a more rigid project structure, is more technical and may require additional tools to implement.

Agile is primarily for software development, uses many Lean principles, and reduces the time for product delivery.

Then in the second episode, I covered Lean in a little more detail. Lean is a great methodology to start with and easy to adapt to many different types of business. It is a composite of tools and techniques developed over years with the contribution of many individuals and companies, particularly the Toyota Motor Company. Lean uses Five Focusing Steps to help companies understand customer requirements, reduce waste, generate flow in their production, and identify and solve company-wide problems.

Now that you are up to speed, let's jump right into our topic for today. So, buckle up because we have a lot to cover and not a lot of time to do it. (music)

3. For this episode, we will dive into Six Sigma. Six Sigma's structure is significantly different from Lean's. Six Sigma is a toll-gated project management method for process improvement. As Lean focuses on waste elimination, Six Sigma projects seek to reduce variation, the cause of unpredictable and unwanted results. Customers have high expectations that can be very precise, specifically when it comes to matters of safety, and the only way to ensure your processes meet these expectations is through statistical process control. Measurements for every aspect of the business are taken and analyzed to determine how to improve performance and customer satisfaction. A company that is performing at a Six Sigma level experiences only 3.4 Defects per Million Opportunities, (DPMO).

4. Before we speak about the tools they share, let's cover two important differences between Lean and Six Sigma. The first concerns profitability. Lean assumes that waste removal will lead to lower costs and better profitability. While that assumption has largely held true, Six Sigma does not

assume this and requires that all projects benefit the company financially. Project champions require the team to calculate the potential Return on Investment or ROI to justify the resources required to carry out a project. The ROI is part of the Business Case, or justification for the project, and helps management determine which projects are the most profitable and which receive priority.

Commented [TS2]: ROI formula: (net return on the investment / cost of investment) * 100%

They also use different methods for finding the cause of problems. Lean is best when the cause of the problem can be identified without intense statistical analysis. Six Sigma projects are only carried out if there is no known cause or solution to the problem. It is used when the root cause of problems is hard to identify, and solutions may only be found through rigid scientific experiments. Six Sigma is essentially the scientific method adapted for businesses.

Commented [TS3]: Root cause: the original or initial source of something

5. Now there is a lot of overlap between the two methods as there are many Lean tools used during Six Sigma projects. As I mentioned in episode 1, they are complementary. For starters, teams will use tools developed in Lean to better understand their process. In the Define phase, value stream and process mapping help identify the current state. And during the Improve phase, it may be necessary to implement Visual Management, 5S and *Heijunka* to show the workers the best way to perform new tasks. And *Andon* systems may be installed to automatically alert the workers that a defect has been created and that they need to stop production before more problems occur.

Six Sigma practitioners also understand the importance of Lean's other principles; value is identified by the customer; waste reduction is necessary; true solutions address the root cause of the problem. All these tools are embraced in Six Sigma, which is why we often see them combined in one

methodology, Lean Six Sigma. But for our podcast, we have to treat them separately because it is easier to understand them that way.

6. Now let's talk about the Six Sigma project model. There are five phases to every project that must be completed sequentially. This means they must be carried out in order; skipping a phase is forbidden. The phases are Define, Measure, Analyze, Improve and Control. After the team completes their work for a phase, they meet with the project's leadership at a tollgate meeting. The team shows the work they have completed and tries to convince the project champion that they are ready to move to the next phase. The champion then approves the team's request or sends them back to work.

If the root cause of the problem becomes evident after some initial study, then a business case is made to implement a solution, and it is put in place. There is no need for a Six Sigma project at this point.

Commented [TS4]: Implement: to put a plan or system into operation

In the Define phase, the team identifies a specific problem that needs to be fixed, justifies the project by showing their boss the financial benefits, and creates a cross-functional team and plan to do it. The goal of this phase is to understand the problem being addressed.

Commented [TS5]: Cross-functional refers to collaboration involving multiple departments, where employees from different areas share ideas and divide responsibilities to work together effectively.

After the project champion is satisfied that the problem is well defined, the team moves to the Measure phase where they quantify the current performance. In the Measure phase, you gather as much relevant data as you can afford to understand everything about the problem.

Once the champion is satisfied that the baseline data has been collected and the problem has been quantified, they permit the team to move to the Analyze phase. In the Analyze phase, you look at the data to identify the root cause for the problem.

Commented [TS6]: Baseline: an imaginary line used as a starting point for making comparisons

Often teams try to skip straight to the Improve phase and implement a solution that has not been properly vetted. I offer a word of caution; this often ends in failure as the problem is not always completely understood. Finding the cause-and-effect link is a crucial step in the project. Solutions can only be effective if they address the root cause.

Commented [TS7]: To vet: to examine something or someone carefully to make certain that it is or they are acceptable or suitable

In the Improve phase, you search for and implement the solutions to the root cause. The team develops and tests solutions in scientific experiments to identify the best way to move forward.

In the Control phase, the team documents and provides training on the new process and monitors the results to ensure that the solution continues to provide the desired benefit. Once the team shows that the new solution is in control and that the new process is being followed, the project can end.

7. Now that we have spoken about its structure, let's talk about Six Sigma's tools. We use the word tool to cover documents, diagrams, maps and activities that help us learn more about our problem and create solutions. For the Define phase we will talk about the project charter and the SIPOC diagram. Then we will discuss some Basic Statistics and how the Measure phase uses the data collection plan and process mapping. To help identify root causes, we will cover cause and effect diagrams and hypothesis testing, and for the Improve phase, we will describe brainstorming techniques and how to design experiments. And we will finish with the Control phase, process monitoring and SOPs. Although it is not a phase per se, it is important to also know how to properly close a project.

8. Now I want to talk about why cross-functional teams are so important and why it is necessary to have a Project Sponsor with significant influence. Most organizations are broken down into functional areas for easier management and organization of work. This can lead to problems if the functions don't

work together. For example, the Design team works in their offices and rarely shares their work with anyone else; the production team is in the factory, and the sales team is meeting with clients. Everyone is focused on their own work. But when issues arise, this isolation can keep individual functions from solving enterprise-wide problems. Enterprise-wide means throughout the enterprise, or company. To break down the barriers to information, the process improvement team must be independent of functional restrictions. Teams need to be able to work with all different functions so they can find and solve root causes of problems. This is where the Project Sponsor's support is so important because they can open doors that would normally be closed.

9. The Six Sigma Belts are a very important part of these teams. In our first episode, we spoke about the Roles and Responsibilities of people on a Six Sigma team, so I won't repeat that here. This is just concerning the belts. A belt is a facilitator with specific knowledge of how Six Sigma projects are managed. The color of the belt indicates their experience and capability to manage projects of different sizes and complexity. There are many companies that train employees at very basic levels and have recently added White and Yellow belts to the lexicon of Six Sigma experts. But I would not trust any one of these to guide or manage a project. So, we will start with Green Belts (GB) as the lowest level of Six Sigma expert.

Green Belts normally have about six months of general Six Sigma training and only work on projects part-time. Although when I started there was no specific training for Green Belts, new curriculum and certifications are available from companies that outline their required knowledge. They can manage smaller projects by themselves, but to gain experience they often assist Black Belts on larger projects. Sometimes, they start their careers as

Commented [TS8]: Curriculum: the subjects studied in a school, college, etc. and what each subject includes

data analysts or team members and find they enjoy project work, so they request additional training to become a Six Sigma belt.

Black Belts (BB) have years of project, leadership and statistical training. They must pass exams and complete high-level projects before they receive their certification. They can lead cross-functional teams without the need of oversight and work as dedicated, full-time resources in the Project Management Office. Their projects must save significant amounts of money to be valid and justify their high salaries.

Master Black Belts (MBB) reach this level after years of project work as a Black Belt and are seen as Subject Matter Experts in many areas of the business. They advise executive leadership and lead enterprise-wide, multi-year projects. They also can develop curriculum and training for lower belts, and it is often required that the manager of the Project Management Office have a MBB certification.

10. Now that you know a little bit about the project structure and who is involved, let's dive into our first phase and talk about what the team will try to accomplish and how they will move forward. This is the Define phase.

There is a lot that happens during the Define phase, but we will only cover two items in depth in the hope that it will give you an idea of what is happening without taking up your entire day. I have a Green Belt course that covers these topics in more detail, but it is about 40 hours of instruction, so I had to summarize it so it would fit into one episode.

Identifying which problems to solve and which projects to approve happens before the project even begins. Aligning your company's goals with your customers, benchmarking your performance against your competition and

Commented [TS9]: Benchmarking: the act of measuring the quality of something by comparing it with something else of an accepted standard

listening to your owners and stakeholders is critical to making sure your Six Sigma projects improve what is most important to your company.

Once the project has been selected, the team must really understand what the customer is telling you. What do their purchasing patterns mean? How have their requirements changed over time? Has your technology advanced so that you can now give them something that will really delight them? When we discuss the Kano model in future episodes, we will talk about how some features are more important than others.

During the Define phase, there are some documents that need to be created to guide the team through the project. We will talk about the project charter in our next slide, but the team will also need a communication plan, a meeting room dedicated to the project and other tools they will use during future phases. These should all be provided by the Project Management Office in advance.

Other management and planning tools will be created during this phase to help the team understand the nature of the project. Affinity diagrams, interrelationship digraphs and others guide the team and help set expectations.

As we are creating new teams for each project, many of the members will be unfamiliar with each other and with how Six Sigma teams work, so they will need to be coached on team dynamics. Team leadership should keep an eye on domineering personalities and work to reduce any personal conflict between members.

11. Now let's talk about one of the most important documents in Six Sigma, the project charter. The charter is a formal document created by the Project Manager, Project Sponsor and other stakeholders, and authorizes the project manager to perform activities using the company's resources.

They serve many purposes. The charter helps the PMO keep track of projects that are underway. This simplifies the company's planning and forecasting for process improvement events. Officially, the charter marks the end of the project selection phase. Of the ideas that were being discussed, this project was officially approved and authorized. The charter is signed by the Project Sponsor during a Kick-Off meeting where all the team members and stakeholders get together to discuss the plan for the project.

Commented [TS10]: Kick-Off: If you kick off a discussion or an activity, you start it

The charter outlines project expectations regarding project scope, benefits, timeline and quality metrics. The team will refer to the charter throughout the project to see if they should maintain their current course of action or change. The charter is a living document, so it may be altered if the company's priorities change.

Commented [TS11]: Scope: the range of a subject covered by a book, programme, discussion, class, etc.; in this case where the project starts and stops

Let's cover 3 important statements in this document.

The problem statement specifies and quantifies the problem, letting the team know how long it has been going on and how it impacts the organization and how the current state differs from our expectations.

The Business Case outlines the Why of the project, the reason the project is moving forward. It covers the project's strategic and financial benefit for the company.

The Scope Statement lets the team know where the project starts and ends. This helps the team focus on the relevant processes and limits the resources the company provides.

There are 6 steps to chartering a Six Sigma project:

Obtaining a problem statement. The problem statement should not try to identify the cause or solution of the problem. If you already know the cause

of the problem, then just implement a solution; you don't need a project in that case.

Identifying the principal stakeholders. These are the internal and external customers that provide the Voice of the Customer.

Creating a macro flow of the process. It is helpful for the team to visualize the process that will be examined and improved. A high-level view is sufficient during this phase, as more detailed maps will be created later.

Commented [TS12]: Macro; large; relating to the whole of something, rather than its parts

Selecting the team members. Again, cross-functional teams are best for Six Sigma projects, preferably filled with diverse team members who can also work across functional lines.

Training the team. Some members of the team may have worked on a Six Sigma project before, but many will need to be trained. This is the responsibility of the Six Sigma belt or possibly the PMO will provide a course.

Selecting the team leader. Yes, the Six Sigma belt and process owner are on the project, but they often have more projects and responsibilities at the same time. There needs to be a dedicated project manager who leads all the daily activities.

12. We spoke about the need during the Define phase to get a high-level view of the process, and the SIPOC tool does just that. It gathers a lot of information in one place and helps the team identify some important data points.

SIPOC is an acronym that stands for Supplier, Input, Process, Output and Customer, and on the document, each has its own column. In the Supplier column, you list all the suppliers that provide something to the process you are investigating. Then in the Input column, you list all the things that they provide. And then you continue by listing the major steps in the Process, all

Commented [TS13]: Acronym: an abbreviation consisting of the first letters of each word in the name of something, pronounced as a word

the Outputs that the Process creates and the Customers that receive the Outputs. This allows the team to get their arms around all the people, processes and technologies that concern the project, and start to show how they influence one another.

Other items listed at the bottom of the document are the Critical to Quality variables or CTQs. These are the measurable characteristics of a product, process or supply that directly affect customer satisfaction. For example, the Critical to Output measurements for croissants at my local boulangerie are that the exterior crust must be dark golden brown, crispy and flaky with an interior that melts in your mouth. These are what the customer demands. And even though they appear subjective, there are some ways to measure them. For the croissant to come out of the oven like that, the Critical to Process metrics are; the oven must be at 400 degrees, and the croissant must stay in there for exactly 18 minutes 30 seconds. Too long and it is burned; too short and it is under-cooked. And the Critical Input Measurements for the suppliers are; a butter that is 80% full fat without any salt, and a flour that has a moderate protein content between 10 and 12%. These are measurables that the team can document to help them start linking problems with causes.

Commented [TS14]: Variable: a number, amount, or situation that can change

13. Okay, this looks like a good place to stop. We will continue with the remaining phases in the next episode. As usual, if you have any questions or comments, you can leave them below or send me an email at info@leanenglishconsulting.com. Alright, until next time be good, and I'll talk to you later.

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1. Part 2 of episode 3: Six Sigma

1. Welcome back for part 2 of our Six Sigma episode. As mentioned before, my name is Tom and I am the host and creator of The Lean English Podcast. This is the third episode of our four-episode series about Lean, Six Sigma and Agile. Check out the previous episodes if you haven't already.

In part 1, we covered the basic structure of Six Sigma and the team make-up. Then we talked about the Define phase and some useful tools that help teams stay on track throughout the project. In part 2, we will cover the remaining 4 phases. But first, let me reiterate that this is just a brief explanation of what the phases are and what they accomplish, and some of the documents the team uses. We will cover these topics in more detail in future episodes.

Now let's get back to the program.

2. So, let's assume the Project Champion is happy with your progress in the Define phase and you make it through your tollgate meeting. Now you must turn to the work of the Measure phase. During this phase, the team will collect data on the process to understand the problem in a quantitative way. But before they do anything, they must understand some basic rules about statistics, so they treat the data correctly. Then they must create intricate process maps that follow the people, process and technology through the company. They must understand what is happening before they can measure the activities. Once they have their maps drawn, they will be able to create a plan to collect the data.

Commented [TS15]: Intricate: having a lot of small parts that are arranged in a complicated or delicate way

3. So, what are the basic rules of statistics that the team needs to learn? Understanding how different data types are analyzed will help with the data collection. All levels of measurement are not the same. Imagine you own a chain of bakeries, and you want to improve sales. You start by collecting data about your business; the list of locations, the number of customers you see

every day, the types of pastries you sell, the amount of butter you use in your recipe, the temperature of the ovens, information like that. Well, you can't treat all the information the same way. For example, if you rank your pastries by sales, the name of the item is a form of Nominal data, and we use Ordinal data to put them in First, Second or Third place.

Nominal data can also be subjective opinions, as when a customer complains that your croissants are not flaky enough. Often, to quantify opinions, businesses use a Likert scale from 1-10 to gauge customers' satisfaction. This is a type of Interval data, like temperature. But even though they are represented as numbers, Interval data can be misleading when analysts use basic mathematical formulas. For example, if you want to reduce by half the time it takes to bake a croissant, you can't just double the oven temperature. An 800-degree oven is not twice as hot as a 400-degree oven. The temperatures represent intervals on a scale, not real numbers. And when you are ranking your sales, the difference between the first and second place pastries may not be the same difference between second and third place.

Nominal, Ordinal and Interval data are useful, but to perform most calculations, you need to collect Ratio data, like time, size and weight. These measurements are real numbers and are used to calculate averages, variances and other important metrics. It takes some time, but the team needs to understand the rules that apply to different types of measurements.

Now, when it comes to data collection, the more samples the better, but costs must be considered. Confidence in the test increases with the sample size, but we must balance our need for certainty with the cost of the collection. Imagine you make 200 croissants a day, but you choose to examine only 5 of them. A sample this small will mislead you because by

accident you may get 5 very bad or 5 very good croissants. But if you examine all 200, then you lose all that revenue for the day.

A popular saying concerning data is, "garbage in, garbage out". It should go without saying, but if the data is not collected accurately, your decisions will be based on data that is just wrong.

Descriptive statistics are population or historical data that we use as a baseline for our current state. When we are testing solutions in the Improve phase, we will compare our baseline with the performance after the solution has been implemented. We want to see if the solution provides a benefit or if the previous process was better. So, the baseline must be as accurate as possible.

The value of Inferential statistics is linked to sample size. When dealing with samples, we often make inferences when we compare them to our baseline. If your team does not understand the differences between these two types of statistics, you will have problems when you perform tests later in the project. We will briefly talk about the importance of Hypothesis Testing later.

One rule of thumb is to always graph the data. Many types of analysis are better understood when they are represented graphically. I am sure there are some people who can look at a table of numbers and understand what they mean, but for the rest of us, it is best to graph the data. Find the best graph that represents the data and stick with it throughout the project. This is also a necessity for any briefings with leadership. If you only have a few minutes with a busy executive, graphs are the best way to show what is happening.

4. As we saw in Lean, process maps can capture the actions of different departments, data about their performance and follow value as it flows through an organization. A critical step in the Measure phase is to map and

Commented [TS16]: Garbage: waste material or unwanted things that you throw away

Commented [TS17]: Hypothesis: an idea or explanation for something that is based on known facts but has not yet been proved

measure the current state as there may be significant disconnect between what we think happens and what actually happens.

Other maps, like this swim-lane map, capture the handoffs as the product moves through a process. You can add colors to represent if the process step is value added (green), non-value added (red), or business value (yellow). Business value represents activities that are not valued by the customer but must be performed due to regulations or limits in technology. On the left side of the slide, the top map was created from the Standard Operating Procedures documents and represents how the process should work. However, the lower map was created after a Gemba walk and some team members followed how the process actually works. You can see from the bottom map that the Gemba walk revealed 3 non-value added process steps that are not in the Standard Operating Procedures. Gemba walks are so valuable because they show the Hidden Factory, the extra work performed that is hidden from management and secretly cost the company time, money and customers.

5. The data collection plan is a shared document that is used to guide the team through the Measure phase. It lists all the process steps that will be investigated, how the step is defined and scoped, the sample size of the collection, who will take the measurements, how the data will be documented and the tools they will use – just about everything. Nothing should be left to chance. There must be significant detail in the plan and training given to the team because much of the data collection will be unsupervised – at times and in places that are inaccessible for the entire team.

Commented [TS18]: Inaccessible: very difficult or impossible to travel to or reach

It is also important that the observer collect all the other environmental data that is available for future reference. Uncontrollable variables like humidity

can impact the product, and so the data should be captured if possible. In our croissant example from earlier, the source of the problem may be that the humidity at one location is too high. If the team does not think of capturing the humidity data, the team may never know what the cause of the problem really is. It may even change the outcome of your project.

Eventually the team proves that they have completed the objective of the Measure phase. They have verified the baseline data that quantifies the problem, and they are allowed to move on to the Analyze phase.

6. The purpose of the Analyze phase is to discover what causes the problem. This is when the team uses the data they collected during the Measure phase to perform root cause analysis.

We know that variation is the main cause of defects. Variation is calculated by measuring the difference between individual samples and the average of all the samples. No matter how consistent your processes are, if you use precise measurement instruments, you can always find variation in the units you produce. The more inconsistency you have in your processes, the more variation you will see in your product.

Commented [TS19]: Variation: a change in amount or level

So, teams track process and product variation, hoping it will lead them to the source of the problem. One way to track it is to use multi-variate studies to map the variation with highly detailed graphs. Then the team can compare data from many dimensions to see where and when it occurs. For example, it may exist between units, as in from one unit to the next – one croissant is burned while the other is perfect. Or you may find variation inside each unit, as when you see that your croissants are burned only on one side. We also see variation change over time, as ovens lose their precision or experienced bakers are replaced by new employees. Multi-variate graphs are quite complicated so we will cover them in more detail in future episodes.

Pareto charts are also useful during the Analyze phase. They use the 80/20 principle to help prioritize which things get investigated. For example, they may show that 80% of your burned pastries are baked by 20% of your bakeries. This helps the team focus on the ovens in those locations. But even though they guide the team in the right direction, they don't provide the information that the team needs to find the root cause. For that we use Cause-and-Effect (C&E) Diagrams, Regression Analysis and Hypothesis Testing.

7. Here are the two most popular Cause and Effect tools, the Fishbone diagram and the 5 Whys diagram. The Fishbone diagram is filled in during brainstorming sessions, when the team reviews all their data and comes up with ideas for potential root causes. Then, they plot them on the chart under 6 categories; Management, Method, Measure, Materials, Manpower and Mother Nature. For example, under Manpower, the company may find the primary cause of some problems is that their workers are not properly trained, while a secondary cause is that the turnover is high. Turnover is when workers leave the company and their replacements need to be hired. If turnover is high, it means that the company is spending a lot of time training new employees, who are leaving without gaining enough experience to become effective workers.

The 5 Whys takes this information and focuses on the root cause by asking the question 'Why' 5 times. Why is turnover high? Because workers are unsatisfied. Why are they unsatisfied? Because they dislike their managers. Why do they dislike their managers? And so on. Eventually you will come to a cause that you can identify to solve.

But Tom, you ask, aren't the Fishbone diagram and 5 Whys a part of Lean? Doesn't Six Sigma have its own tools? Isn't there any statistical analysis we

can perform to identify cause and effect? Yes, there are different analyses we use to test our assumptions before we make any decisions. There are too many tests to cover here, but we will talk a little about regression analysis and hypothesis testing.

Commented [TS20]: Regression; a method in statistics (= the study of facts that can be shown by numbers) which compares the way in which two or more related sets of numbers have changed over a particular period:

8. Regression analysis tests whether an input variable, like butter, has an influence on an output variable, like customer satisfaction. The test calculates the influence and provides a formula that can be used as a predictive model. Therefore, if the input variable greatly influences the output, if the relationship is strong, then you will be able to accurately predict the outcome when the input changes. This is best explained with an example.

To continue with our croissant project, we ran a test to see if the amount of butter in the recipe had an impact on the customers' satisfaction score. We made batches of pastries each with a different amount of butter, gave them to customers and asked them to rate them on a scale of 1-10. So, for each batch we have an average satisfaction score. We use this data for our test. After the test, we use the formula to calculate what the regression would have predicted for each data point. At 110 grams, the customers gave the croissants an average score of 6.7. Those scores are represented by the blue line. But when we use the regression formula, it gives us a score of about 7.3. These scores are represented by the orange line. What we want is a regression line that closely resembles our actual data because we want to be able to accurately predict an outcome (customer score) if we are given an input (butter amount). Remember we are trying to show that there is a relationship between these two variables. But we see throughout the graph, the regression formula does not do a very good job of prediction, even though we suspect that there is a relationship.

This is because one limitation to a regression analysis is that the relationship between the input and output must be linear. For example, every additional gram of butter should increase my customer score.

But if we look at the graph closely, we see that the relationship butter has with customer satisfaction is curvilinear – it is curved, not straight. It doesn't follow a straight line because the score seems to peak around 124 grams of butter per batch, and then the scores decrease as too much butter is added.

9. We can see from these graphs that if we perform 2 tests, one for the scores before 124 grams and one for the scores after, we can fit two formulas that offer good predictability. Now two models fit very well, where one model failed. The amount of butter is truly related to the customers' scores, just not in a linear way through all possible inputs. For the project's purposes, the right amount seems to be between 124 and 128 grams.

10. We use hypothesis testing to see if the data proves if the impact of the variable is statistically significant or merely coincidence. We are asking the question, is it probable that these data sets are actually the same even though they appear different? If the P-value of the test is low, we reject the hypothesis that they are the same.

Commented [TS21]: The p-value shows the likelihood of your data occurring under the null hypothesis. P-values help determine statistical significance.

For example, let's say the company has 3 bakeries and recently opened a 4th. We think that part of our problem may have something to do with the old equipment and baking process in our older bakeries. So, we run a hypothesis test to see if they score as well as the one we opened just 6 months ago. We take the average weekly score that we received from sites 1, 2 and 3 and compare it with 6 months of weekly data from Site 4. Note that there are more scores from sites 1, 2 and 3 because they have been collecting data from those bakeries for longer. The hypothesis we are testing, or null

hypothesis, is that there is no difference between the average scores. The alternative hypothesis is that they are different.

We perform a T-Test and compare the data. The averages of 7.22 and 7.66 are similar, but the test's P-value of 0.00, highlighted in yellow at the bottom of the table, tells us there is very little chance the average scores are the same. The scores from Site 4 are higher. If there was suspicion that Site 4 was a problem, this test proves otherwise.

I know this seems like a lot, but we haven't even scratched the surface. There will be many more episodes on hypothesis testing in the future. This level of probability and statistics is difficult for many to understand and is why so many organizations prefer Lean to Six Sigma.

Once we prove we have identified and validated the root causes of the problem, we can move to the Improve phase.

11. From our work in the Analyze phase, we have a list of variables that we know contribute the most to our outcome. Now, the purpose of the Improve phase is to generate, test, and implement solutions that address root causes.

Our first task is to brainstorm and prioritize ideas to test during our experiments. This includes risk and cost-benefit analyses that help us avoid creating solutions that are dangerous or too expensive. Then we must design experiments where we test our assumptions, run some pilots and try to optimize those variables for the highest level of quality. And after we have identified proven solutions that eliminate root causes and improve performance metrics, we move to implementation.

Commented [TS22]: Optimize: to make something as good as possible

12. During brainstorming sessions, the team considers all the work that has been completed to this point and creates a plan to solve the problem at the

root cause. These team meetings should be organized where ideas are openly shared. Subject matter experts and all team members should be welcome to attend. The team maps the impact points, identifies possible solutions and begins creating plans for implementation. The Project Champion is briefed at the end of the meeting and determines the course of action.

In addition to brainstorming, the team may use the Theory of Inventive Problem Solving (TIPS) model for generating solutions. The format is to take your specific problem and then transform it into a generic problem. Then find a generic solution to solve the generic problem, and finally a specific solution for your project's problem. The theory behind TIPS is that all types of problems have been solved by someone, somewhere in the world; so instead of trying to reinvent the wheel, just steal their idea.

13. Now that solutions have been identified, it is time to test them. We use experiments to tell us if a new solution makes a significant impact toward fixing our problem, or if our current method can be improved in some way.

A designed experiment saves the company time by ensuring that each level of each variable is assigned to a run, that the results are properly measured and that the best solution is identified.

So, imagine there is a baking competition in a month, and we want to enter our croissants. We want to determine the best possible texture for our pastries. We can adjust the fat content of the butter, the time it spends in the oven, and temperature of the oven. Fat content, time and temperature are the factors or independent variables. A run is the experiment with the factors set at a precise level. The 3 Factors each have 2 Levels, giving us ($L^F = 2^3$) 8 runs for a full factorial experiment. Each run is replicated 5 times, which means we use this particular recipe to make 5 batches of croissants. Then we

offer them to customers and ask them to rate them. The result in the columns is the average score given by testers on a scale of 1 – 10. For example, the second batch of croissants that uses the recipe from Run 4 was given an average score of 8.

14. In order to see which recipe works best, we create a main effects chart. A quick view of the main effects charts show that there is a difference between the average scores for butter, time and temperature factors. The croissants made with butter with 80% fat received higher scores on average, as did croissants that baked for 18 minutes at 190 degrees. We will discuss how to calculate the interactions between these factors and levels in future episodes, but this lets us know that we are investigating the right things.

With these experiments we have implemented proven solutions that eliminate the root causes and improve performance metrics, so we can move to the Control phase.

15. Now that we have created and implemented our solution, during the Control phase we ensure that the gains we achieved are maintained over time. We create a Control plan that defines how the new process will be monitored and controlled. This will include a risk analysis and response plan to predict possible problems and minimize their impact.

Reinforcing proper procedures is mandatory for success. Understanding Change Management strategies is essential as we develop and deploy new training and update materials for all employees. A large part of these efforts will be to use formal documents to standardize how we will work in the future.

Now let's look at Process Monitoring and Standard Operating Procedures.

16. Statistical Process Control (SPC) is the use of statistical analysis and graphics to monitor and understand the variation in process performance. The goal is to create Control Charts that quickly show if the process is still performing as expected, or if it has regressed. Control limits are calculated and drawn on the chart. As we monitor our performance, all the units we measure should remain between these limits. However, if we measure a unit and the measurement is above or below our limits, this means it is possible that the process has reverted to its previous performance. For example, if increase the size of our croissants, and set the control limits between 15 and 16 centimeters, we will know there is a problem if we start to see some measuring below 15 centimeters.

Control plans are generated during the Control phase to provide instructions on how to properly monitor new processes and respond to poor performance. In the plan on this slide, the "Y" metric is the outcome measurement, the size of our croissant from the previous example. The "X" metrics might be the temperature of the oven or the amount of flour being used. The unit of measure will be centimeters; the target will be 15.5 with the control limits between 15 and 16. The Process Owner will be the head baker; the system they use will be the bakery and its equipment and 'what to check' will be the length from end to end.

17. And as an overall Change Management plan, new SOPs need to be written to outline the process steps in detail in accordance with business policies. These files are the ideal form of documentation to ensure sustainability of improvements. The Process Owner and Process SMEs should help author the SOPs, while the entire team should validate them. Care should be given to write them in the language most easily understood by the user, with graphics and visual cues to make comprehension immediate. The team should incorporate them into all training programs, and they should be

Commented [TS23]: Sustainability: the quality of being able to continue over a period of time

made available in all the applicable workstations and in the PMO library. Previous editions need to be destroyed to reduce confusion.

Once the team has created a stable, sustainable process and put controls in place to prevent regression, the project can be closed and everything handed over to the Process Owner.

18. To formalize the end of the project, after the Control tollgate meeting, the team should meet with the Process Owner and workers to hand over responsibility for the change and the solution. This will ensure that any questions about the new process are answered and the team members can return to their jobs without any worry. The team should also celebrate with a party, and leadership should publish the project's results throughout the company. This will help promote and raise awareness of the benefits of Six Sigma projects and reward the team for their efforts.

19. And just as Six Sigma projects must come to an end, so too must this episode. I know it's a sad time for everyone, but we must be strong. There will be another episode soon, covering the basics of Agile, so you have that to look forward to.

If you have reached the end of this podcast without falling asleep or jumping off a cliff, your award for valor will arrive in the mail in 6 to 8 weeks. As always, for a written transcript of the podcast, please visit my website at leanenglishconsulting.com. And while you are there, please let me know what you think of the episode and tell me if there is a specific topic you would like me to cover. All right; that's it for today. Thanks for listening. Until next time, be good and I'll talk to you later.