THE POWER OF CONTEXTUAL LEARNING: USING THE JUICE SPC GAME TO TEACH CONTROL CHARTS IN OPERATIONS MANAGEMENT

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Full paper
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ABSTRACT

We introduce a new way to teach a complex topic in business education called Statistical Process Control (SPC) through a newly developed simulation called the Juice SPC Challenge. We noticed that learners often find it hard to grasp SPC concepts when taught using traditional methods like lectures and textbooks. The Juice SPC Challenge offers a hands-on experience, letting participants apply as they learn in a simulated real-world context. Using a well-known framework, we evaluate the effectiveness of contextual learning, focusing on how participants react to the simulation and any changes in their attitudes towards the subject. We surveyed 66 learners after they completed the challenge and found that they reported significant learning gains. Specifically, they felt more confident in tackling complex problems, a key goal in business education. The simulation also helped learners understand when and how to use control charts, a crucial tool in SPC. They learned to differentiate between creating and monitoring control charts, a common area of confusion, and how to make decisions based on control chart data. The simulation provided immediate feedback on their decisions, something not possible with traditional teaching methods. Our findings contribute to the ongoing debate about the best ways to teach business topics, showing that experiential learning methods like our simulation can offer significant benefits.

INTRODUCTION

In Operations Management (OM) education, learners often struggle with the demanding nature of the subject. The literature highlights several reasons for this struggle, such as the necessity for problem-solving in multifaceted environments (Costantino, Di Gravio, Shaban, & Tronci, 2012), the imperative of critical thinking amidst conflicting objectives (Miyaoka, Ozsen, Zhao, & Cholette, 2018), the intricacies of probability and statistics (Balakrishnan & Oh, 2005), and the demands of quantitative problem-solving (Bicheno, 2014). Beyond these complexities, students frequently lack practical exposure to operational processes, which hinders their ability to contextualize their learning. While they might demonstrate proficiency in theoretical calculations, such as utilization, control limits, and safety stock levels, the application of these concepts in dynamic, real-world scenarios remains a challenge (Leitão, Navarro, Cameira, & Silva, 2021). This disconnect, coupled with a perceived lack of relevance to their prospective careers (Polito, Kros, & Watson, 2004), often results in students merely aiming to pass their OM courses.

Statistical Process Control (SPC) stands as a particularly challenging topic in OM, perplexing not only students but also seasoned business professionals (Bober & Zgodavová, 2011). Given its foundation in probability theory, an inherently counterintuitive quantitative domain, SPC often proves elusive in both comprehension and practical application (Balakrishnan & Oh, 2005). Conventional pedagogical approaches, such as lectures, predominantly impart theoretical knowledge, leaving a gap in the practical application skills (Burch et al., 2019). Recognizing this gap, We have developed the Juice SPC Challenge, an experiential simulation exercise designed to bridge theory with contextual application.

INTRODUCTION TO STATISTICAL PROCESS CONTROL

Woodall (2000) defines SPC as a suite of methodologies aimed at comprehending, monitoring, and refining both manufacturing and service operations. A deficient understanding of SPC can lead to its misapplication, incurring substantial costs for organizations (Wachs, 2005). Therefore, imparting a robust understanding of SPC is paramount in OM education.

At the heart of SPC lies the discernment of how variations in specific quality metrics influence a process. These variations are divided into common and assignable categories. While common variation emanates from the inherent characteristics of a process, assignable variation arises from external disruptions. Control charting, a cornerstone of SPC, aids in distinguishing these variations. It leverages probability theory to detect potential assignable variations, ensuring that decision-makers respond appropriately to process variability.

TEACHING METHODOLOGIES IN STATISTICAL QUALITY CONTROL (SQC) AND STATISTICAL PROCESS CONTROL (SPC)

The pedagogical landscape of Statistical Quality Control (SQC) and Statistical Process Control (SPC) is due for significant change, driven by the limitations of traditional teaching methods and the advent of more experiential learning approaches. Traditional lecture-based learning, while efficient, has been found to be cognitively taxing on students, limiting their understanding and retention of the material. According to research by O'Leary (2017), the cognitive load imposed by lectures often hampers the students' ability to fully grasp the nuances of the subject matter. Kicken, Brand-Gruwel, Van Merriënboer, and Slot (2009) further elaborate that this form of pedagogy fosters a dependency on the lecturer, thereby undermining the development of self-directed learning skills, which are increasingly becoming essential in the modern job market.

Similarly, textbook problems, although straightforward, often lack the contextual relevance that could make the subject matter more relatable to students. A study by Kim and Pak (2002) found that an increase in the number of textbook problems solved showed little correlation with a deeper understanding of the subject. This lack of contextual relevance often results in SPC being relegated to just another academic problem-solving method, thereby failing to impart a conceptual understanding of its real-world applications. The absence of real-world context in textbook problems creates a disconnect between academic learning and practical application, which is a gap that needs to be addressed.

Recognizing these limitations, educators have increasingly turned to experiential learning exercises, especially in the teaching of Operations Management (OM). Ammar and Wright (1998) have long recognized the ineffectiveness of traditional lecture and textbook-based instruction and have advocated for more experiential-based delivery methods. Various experiential exercises have been developed to teach SPC and control charting. These range from the use of lengths of string (Fish, 2007) to the weight of M&Ms in bags (Lembke, 2016) for generating variable data. However, these exercises often fall short in delivering a realistic context and visual experience that can truly engage and motivate students. Coy (2016) argues that while these exercises serve the primary objective of constructing control charts, they often fail to deliver a realistic context and visual experience to motivate student learning.

It is in this context that the Juice SPC Challenge emerges as a timely solution to these challenges. The game aligns well with the research findings of Oberoi (1996) and Sun and Gao (2015), who emphasize the importance of hands-on experiences in SQC and SPC education. Oberoi (1996) offers students a tangible grasp of SQC by involving them in the actual production of parts and the application of SPC techniques. Sun and Gao (2015) take a different approach, using catapult shooting experiments to allow students to apply theoretical knowledge in an applied context. By allowing students to apply theoretical knowledge in a simulated real-world environment, the Juice SPC Challenge bridges the often-cited gap between theory and practice.

Furthermore, the SQC and SPC education challenge resonates with the insights of van Delft (2002) and Olds and Knowler (1949), who stress the need for a curriculum that is aligned with industry needs. van Delft (2002) contributes to this by introducing classroom experiments that focus on inspection and sampling plans, thereby providing a roadmap for curriculum design. Olds and Knowler (1949) go a step further by offering a comprehensive guide for SQC education, categorizing courses into different types, and emphasizing the need for post-course follow-up. By simulating real-world scenarios, the Juice SPC Challenge prepares students for the challenges they will face in the industry, thereby making their education more aligned with market demands.

Timmer, Gonzalez, and Borror (2011) and van Delft (2002) have highlighted the potential of active learning methodologies in SQC and SPC education. Timmer et al. (2011) focus on the significance of active learning and higher-order cognitive skills, advocating for a more engaged approach to teaching. van Delft (2002) complements this by introducing in-class experiments that not only enhance SQC training but also emphasize the importance of hands-on experiences. The Juice SPC Challenge serves as an active learning tool that engages students cognitively, allowing them to explore, experiment, and make decisions in a controlled environment. This fosters the development of higher-order cognitive skills, which are essential for both academic and professional success.

The Juice SPC Challenge is not merely an educational tool; it is a strategic response to the evolving needs and challenges in SQC and SPC education. It addresses the limitations of traditional teaching methods, aligns with current pedagogical research, and most importantly, prepares students for real-world applications. As the field of SQC and SPC education continues to adapt and evolve, the Juice SPC Challenge is a tool that promises to reshape how SPC concepts are taught. We argue that the integration of the Juice SPC Challenge into SQC and SPC education is valuable and supported by a wide array of academic research. It is a timely and relevant addition to the ongoing discourse on effective pedagogical strategies in this field. The game's multifaceted approach to learning—combining theory, practice, and active engagement—makes it an invaluable tool for SQC and SPC education. It promises not only to enhance the learning experience but also to produce graduates who are better prepared for the complexities and demands of the contemporary job market.

LEARNING OBJECTIVES OF THE JUICE SPC CHALLENGE IN OPERATIONS MANAGEMENT EDUCATION

In the context of an undergraduate core operations management course, which is a foundational requirement for all business majors, the Juice SPC Challenge has been designed to provide students with a comprehensive understanding of Statistical Process Control (SPC) in a realistic setting. While the current implementation of the Juice SPC Challenge was tailored for this specific audience, it's worth noting that the simulation possesses capabilities that extend beyond these foundational objectives. Upon successful completion of the Juice SPC Challenge, participants are expected to:

1. Comprehend the Nuances of Control Charts:
    - Distinguish the distinct phases of creating, monitoring, and interpreting control charts, understanding the significance and application of each phase in real-world operations management scenarios.
2. Master the Creation of Control Charts:
    - Construct x-bar, r, and p charts for processes that are in control, ensuring they can effectively monitor and manage quality in operational settings.
        a) Accurately compute centerlines (x-barbar, R-bar, and p-bar) derived from raw data.
        b) Determine the upper and lower control limits, essential for identifying variations and ensuring process consistency.
3. Efficiently Monitor Processes Using Control Charts:
    - Plot control chart data on pre-existing charts, ensuring real-time monitoring and swift identification of potential issues in a process.
4. Analyze and Interpret Data Variations:
    - Discern between common and assignable variations in data, a critical skill for ensuring consistent quality and addressing potential issues.
        a) Pinpoint out-of-control samples, ensuring swift identification and rectification of quality issues.
        b) Recognize runs, specifically when X consecutive samples lie above or below the centerline, indicating potential systematic issues.
        c) Detect trends, when Y consecutive samples exhibit a steady increase or decrease, signaling potential shifts in the process.
        d) Detect 2 points near a control limit, suggesting that the process has changed.
5. Implement Effective Decision-Making Strategies:
    - Based on the insights derived from control charts, make informed decisions to address and rectify assignable causes, ensuring the consistent quality and efficiency of operations.

THE JUICE SPC CHALLENGE DESIGN

In alignment with the evolving pedagogical needs in SQC and SPC education, the Juice SPC Challenge has been designed to address the limitations of traditional teaching methods while incorporating the benefits of experiential learning. Developed on an Excel VBA platform for intuitive user experience, the Juice SPC Challenge offers a tiered learning approach, where the complexity of the simulation increases as users successfully complete the required tasks (Wood, 2007). The simulation is set in the context of a juice bottling company, located in the Netherlands, that is in the process of franchising its operations to America. This setting not only provides a realistic international backdrop for the application of SPC techniques but also aligns with learning objectives.

Welcome to the complex and rewarding world of the Juice SPC Challenge simulation. In this strategic endeavor, you will assume the role of a Quality Manager at our distinguished orange juice bottling operation based in the Netherlands. This operation is recognized for its high-quality 0.33-liter servings of orange juice, a testament to an intricate, data-driven process that is now deemed a benchmark for all future company lines. Your challenge is to effectively transfer this benchmark standard to a new franchise operation in the United States.

The quality of our product is underpinned by two crucial attributes: the exact fill level in each bottle and the consistent orange color of the juice. The maintenance of these variables is a sophisticated balancing act, perfected over time in our Netherlands operation. The primary task ahead of you involves recreating this balance in a new, American environment.

Utilizing Statistical Process Control (SPC), your mission is to leverage data from our Netherlands operation to create control charts. These charts will serve as the foundational blueprint for the American franchise. You will be expected to manage the statistical analysis of the fill level data to understand both the mean and variation in fill level and oversee the control of color variation within the juice.

You will also encounter natural process variations that result in the production of green juice. While this phenomenon is normal, it is our responsibility to ensure it is kept within acceptable limits as defined by our customer expectations and brand standards. To do so, you will have to establish the proportion of acceptable green juice production, which forms part of your task.

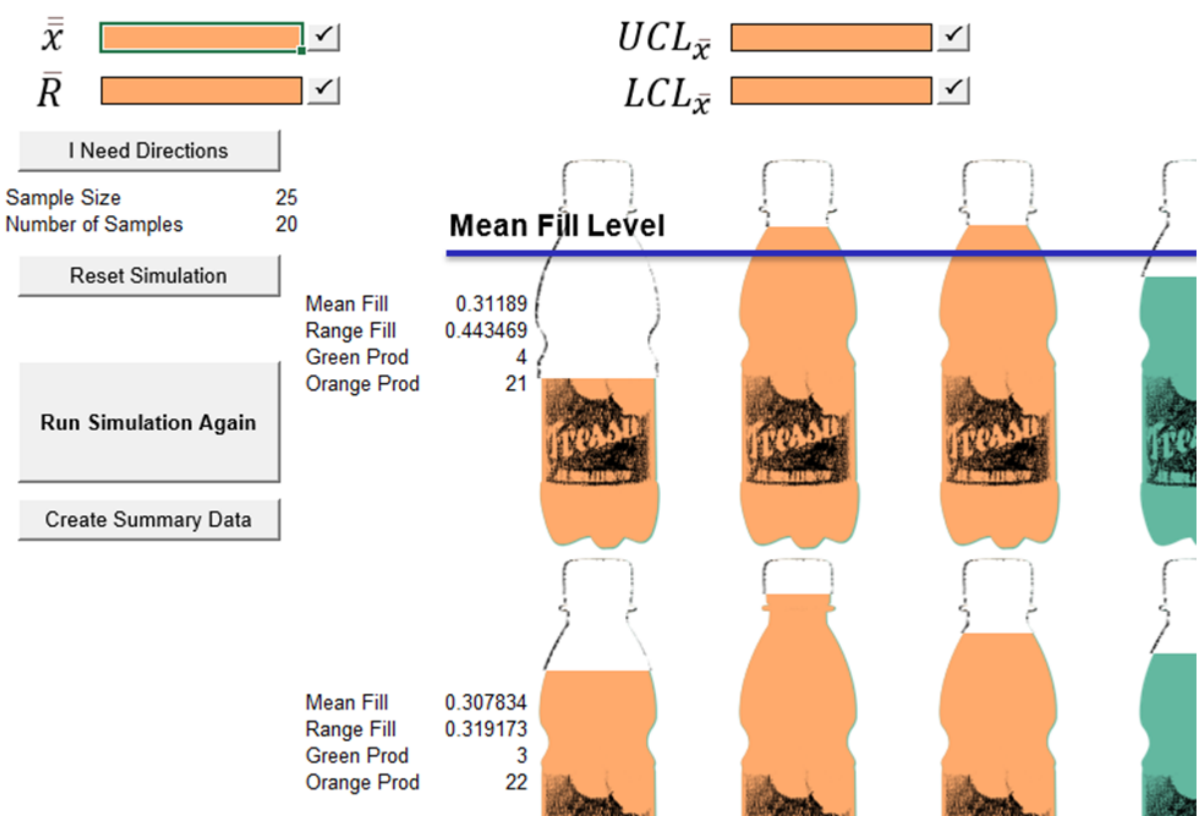
Before you can open the American franchise, three essential control charts must be assembled: the X-bar chart for fill level, the R chart for fill variation, and the p chart for the permissible proportion of green juice. The completion of these charts is a pivotal step towards the successful replication of our Dutch operations in America.

Prepare yourself, Quality Manager. Your journey will require astute analytical skills, a keen understanding of process controls, and an unwavering commitment to maintaining product quality standards. The "Juice SPC" challenge is a unique opportunity to demonstrate your ability to ensure our orange juice remains synonymous with excellence, regardless of geographical boundaries. Your successful navigation through this simulation will ensure that we continue to offer consumers the same exceptional quality, be it in Amsterdam or Austin.

The Netherland plant simulation interface is designed to display data for the in-control process, this interface provides learners with a hands-on opportunity to engage with real-world scenarios. Following the instructions outlined in Appendix A, learners are required to configure essential parameters such as sample size and number of samples and initiate the simulation process. Upon running the simulation, the interface displays all the requisite raw data needed for calculating the centerline and control limits for three key control charts: Mean (x-bar), Range (R), and Percent Defective (p).

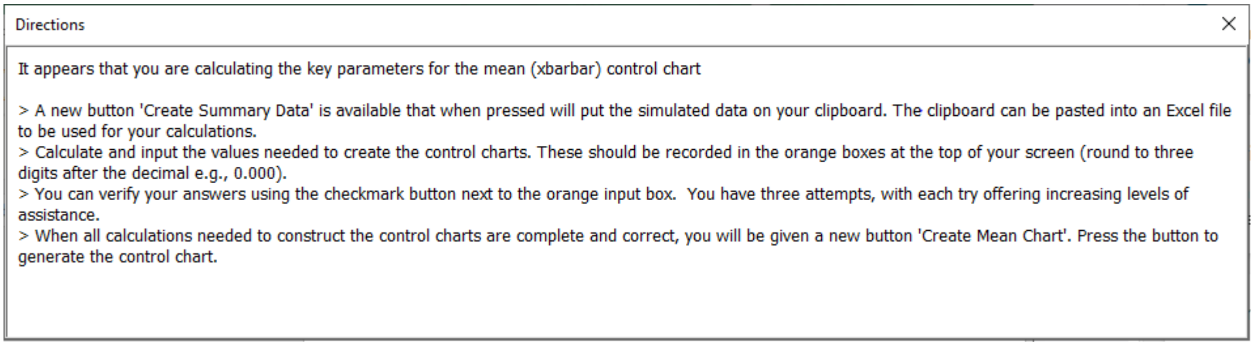
Visually, the interface is designed to offer a comprehensive view of both variable and attribute data. Specifically, learners can observe the fill level, which serves as the variable data, and the color coding—either orange or green—as the attribute data for the samples configured. This visual representation, as depicted in Figure 1 for the Netherlands plant interface, enhances the learning experience by providing a tangible context in which theoretical knowledge can be applied.

FIGURE 1
Netherland plant interface



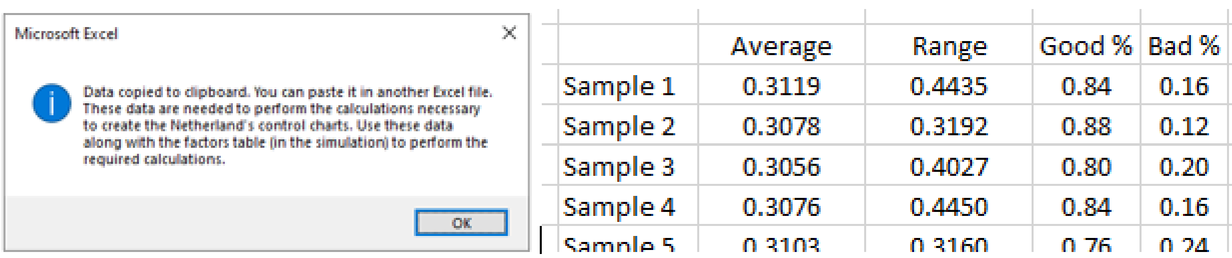
Incorporated within the Netherland plant interface are a series of help features designed to assist learners in effectively navigating the simulation and completing the requisite tasks. These features are designed to provide real-time guidance, thereby enhancing the user experience and facilitating a more seamless learning process. The first notable feature is the "I Need Directions" button, which offers context-sensitive information based on the current status of the simulation. Should a learner find themselves confused, this function provides detailed guidance on the next steps to take, as illustrated in Figure 2.

FIGURE 2
"I Need Directions" Feature



The second feature is the "Create Summary Data" button, which serves the purpose of exporting a summary of the simulation data. As depicted in Figure 3, this exported data is helpful in performing the necessary calculations for control chart parameters. This feature is particularly useful for learners who wish to analyze the simulation data in greater detail.

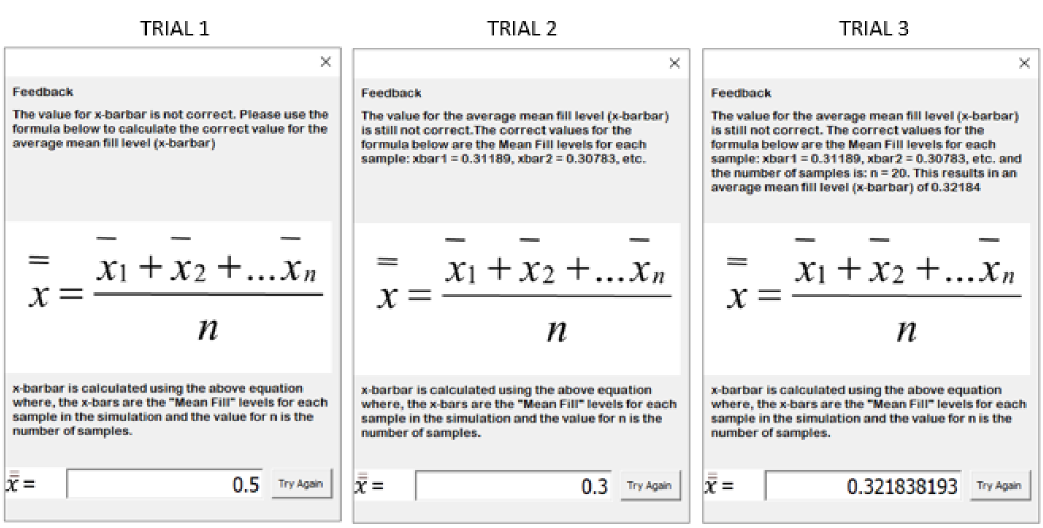
FIGURE 3
"Create Summary Data" Feature



	Average	Range	Good %	Bad %
Sample 1	0.3119	0.4435	0.84	0.16
Sample 2	0.3078	0.3192	0.88	0.12
Sample 3	0.3056	0.4027	0.80	0.20
Sample 4	0.3076	0.4450	0.84	0.16
Sample 5	0.3103	0.3160	0.76	0.24

Lastly, the interface includes check buttons adjacent to each input field. These buttons serve a dual function: they not only validate the learner's input but also generate tailored feedback to guide the learner toward the correct answer, as exemplified in Figure 4.

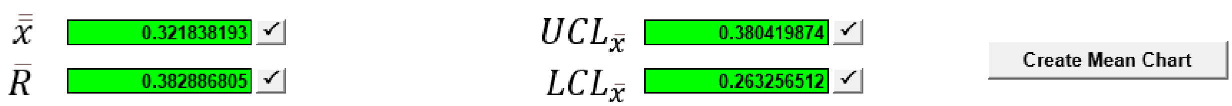
FIGURE 4
"Check" Answer Feature



Together, these help features are designed to support the learner in successfully completing the simulation tasks without having to rely on the textbook or written instructions. They embody a user-centric approach implemented in the simulation design.

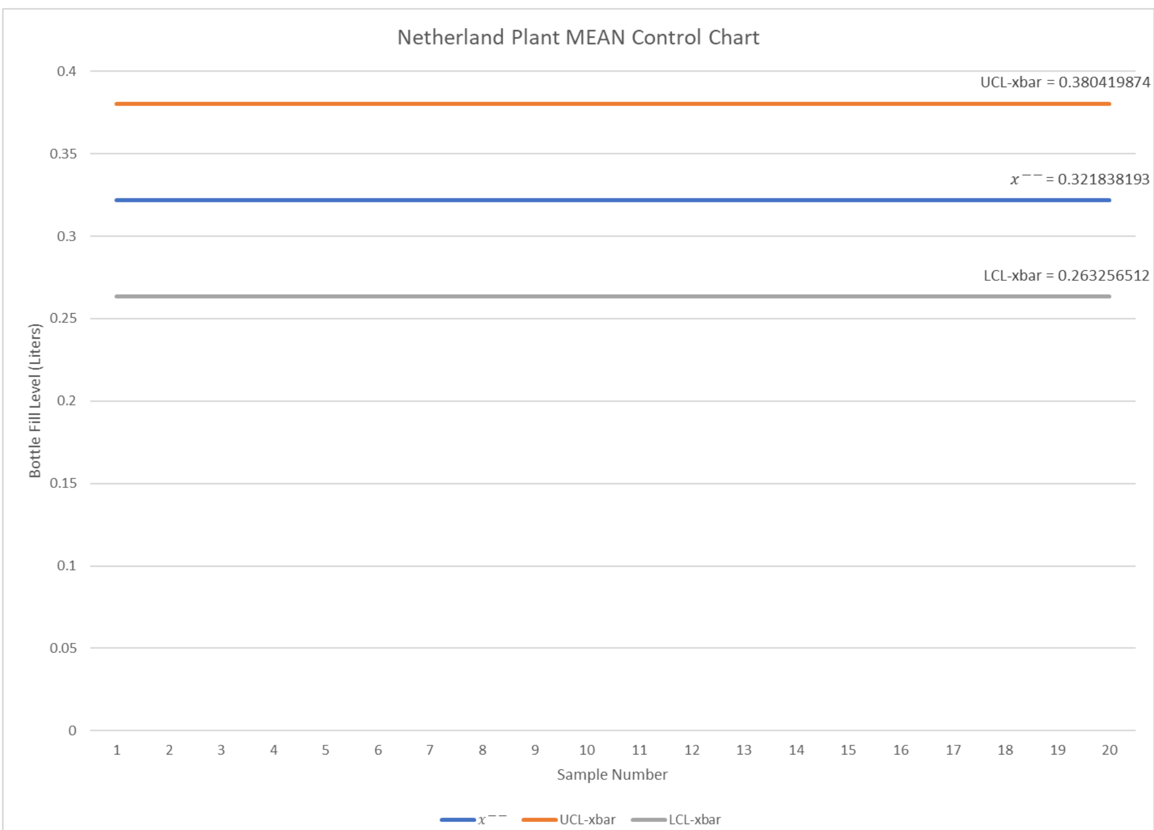
When all the values needed for a control chart have been entered correctly, a new button, "Create XX Chart" where XX is either Mean, Range, or p. Figure 5 is an example of the completed data and the corresponding new button for a mean chart.

FIGURE 5
Example of correct values and generated "Create Mean Chart" button



Clicking on the "Create XX Chart" button will generate a graphical display of the control chart for the in-control (stable) process as seen in Figure 6.

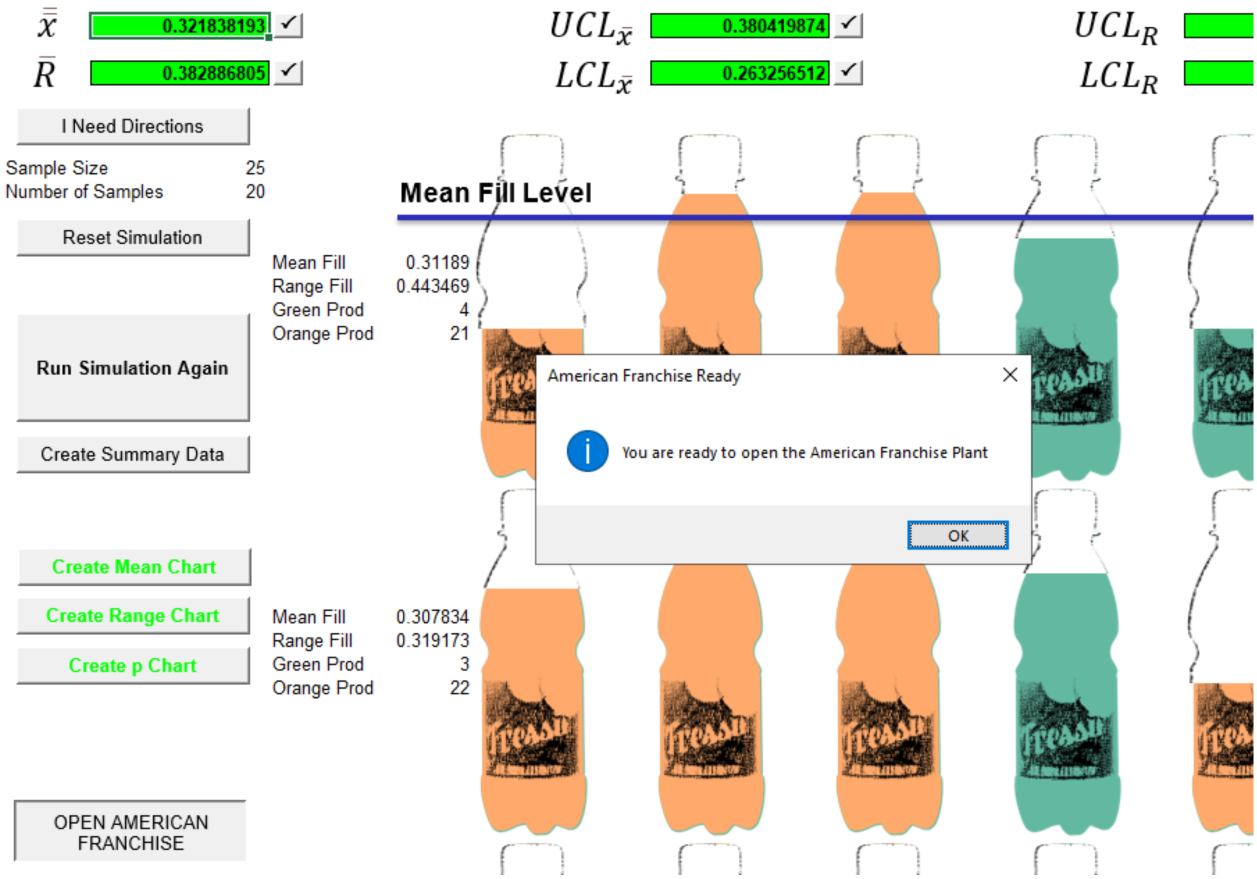
FIGURE 6
Control chart for in-control Netherland plant process



Once all three of the required control charts have been created (e.g. after all control chart calculations are correct), the franchise operation, located in America, can be opened using the "OPEN AMERICAN FRANCHISE" button in Figure 7.

The American franchise plant is opened with the following narrative. The learner is tasked with plotting and interpreting control chart data generated by running various scenarios.

FIGURE 7
When ready to open the American franchise



Welcome back, Quality Manager, to the second phase of your strategic journey in the Juice SPC Challenge simulation. Having established the standard process of our Netherlands plant on the control charts, you now stand at the cusp of expanding our operations into the American market. Your diligence and precision thus far have created a benchmark. As the new franchise owner, your goal is to faithfully replicate the standards of the original Netherlands plant in the new American operation.

The American Franchise

Your next task unfolds in the throes of our American bottling line. Here, you will be generating data, and plotting it on the control charts previously derived from our Netherlands data. Remember, the essence of this task lies in ensuring our American franchise mirrors the impeccable standards of the Netherlands operation.

During your observations, should you notice any discrepancies such as an out-of-control sample, a run, or a trend, it is your responsibility to intervene. Making informed decisions based on these observations is pivotal to bringing the process back under control. This is not just a test of your analytical prowess but also a testament to your ability to maintain our high-quality standards under pressure.

The successful setup of the American bottling line involves completing various scenarios. Owing to the inherent random variations in nature, you may need to make several rounds of decisions to stabilize the process. Each triumph not only strengthens the American franchise but also brings you closer to your desired promotion.

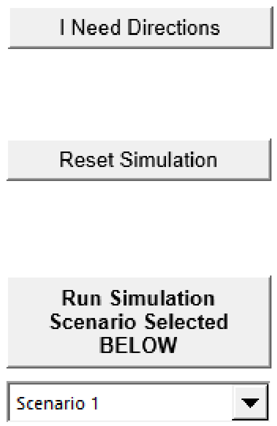
Once you have managed to bring all the scenarios under control, we will acknowledge your commendable efforts. As a token of appreciation for your diligence and commitment, you will be promoted to the esteemed role of Chief Operations Officer (COO) of the new American franchise. This prestigious role comes with an annual salary of $450K, a testament to the significance of your responsibilities.

As you step into this second task, remember that this is not just a simulation. It's a reflection of your ability to ensure that our orange juice continues to symbolize excellence, regardless of the geographical boundaries. Your meticulous efforts will guarantee that the quality our consumers have come to love in Amsterdam is the same quality they will relish in Austin.

The journey to becoming the COO begins now. Your decisions will shape the future of our American *franchise. It's time to bring the Netherlands' legacy to American shores. Best of luck, Quality Manager! The orange juice quality that our consumers love is now in your hands.*

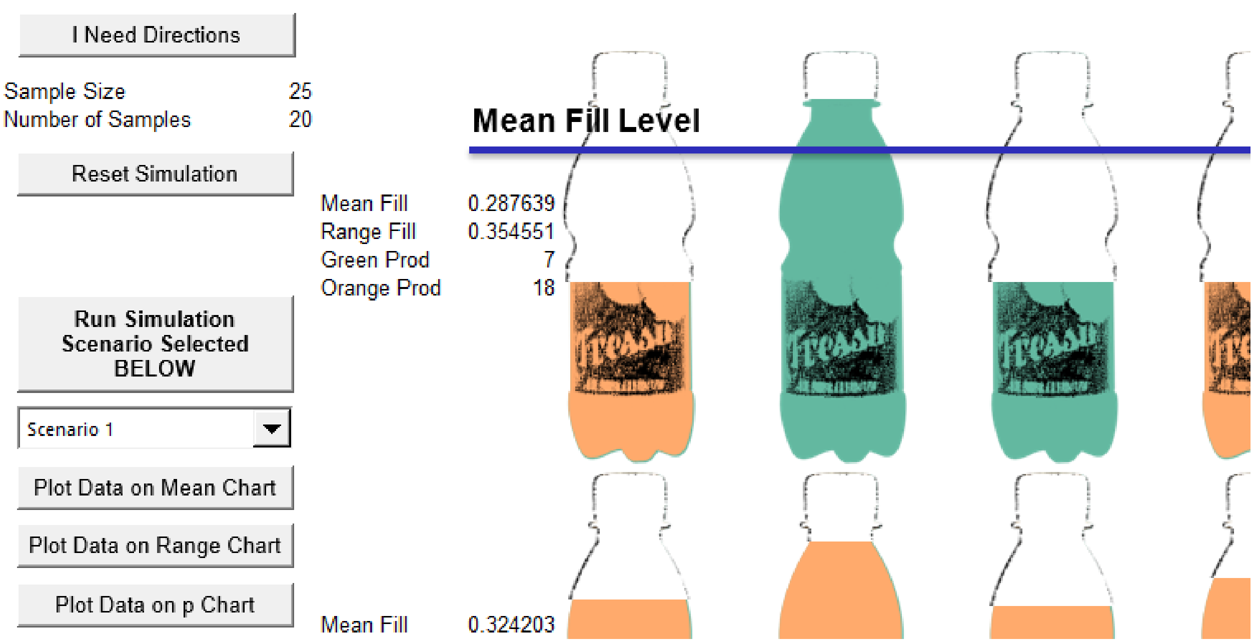
The selection box, in Figure 8, allows the learner to choose a specific scenario to run. We have generated 24 possible scenarios that produce control chart data that demonstrate five possible control chart conditions for each control chart type. These conditions include a process in control, out of control, trends, runs, and two points close to control limits. The 24 scenario conditions are randomized so that scenario 1 is different each time the simulation is reset.

FIGURE 8
American plant scenario selection interface



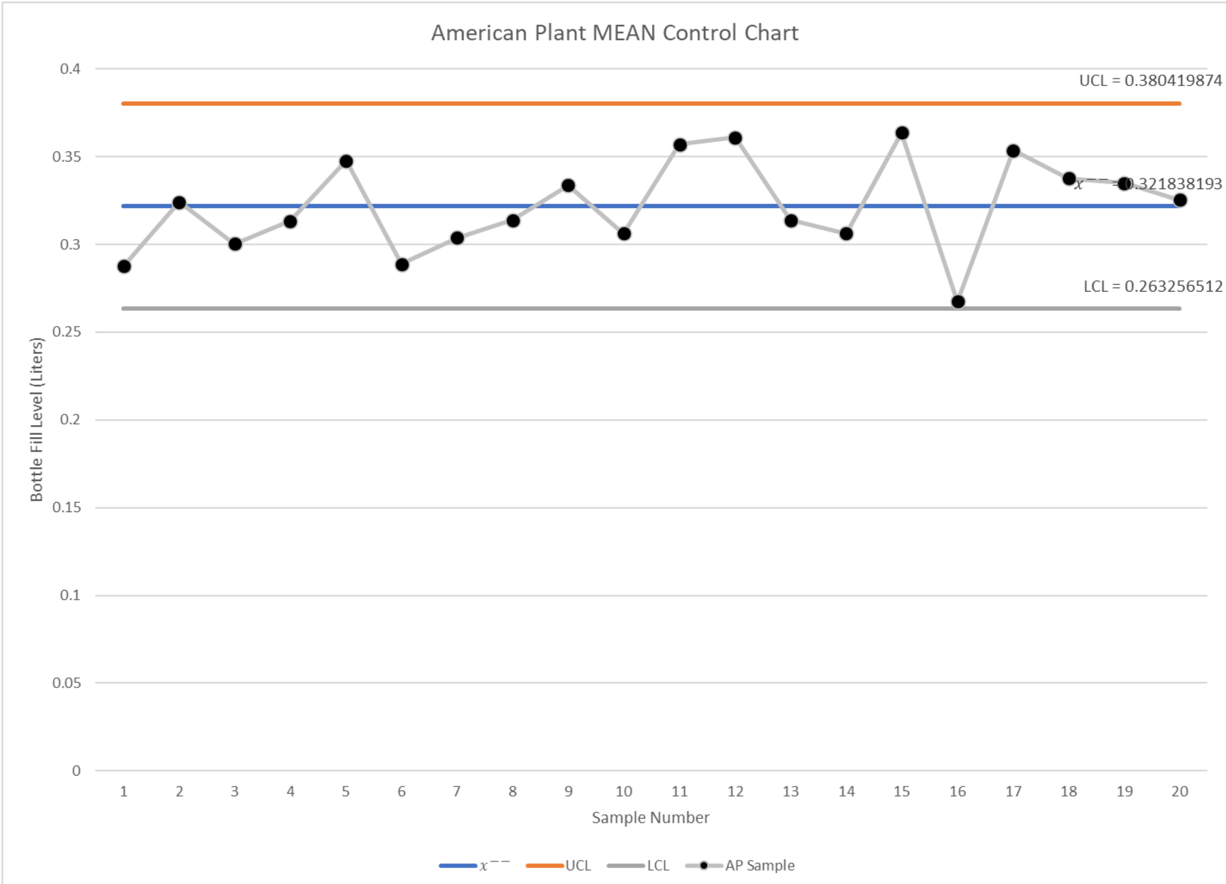
Once the "Run Simulation Scenario Selected BELOW" is pressed, the American franchise data for the scenario selected is run. Three additional button controls are created, allowing the learner to plot the simulated data on the Netherlands plant's control charts. A sample simulation result is shown in Figure 9.

FIGURE 9
American plant scenario selection interface



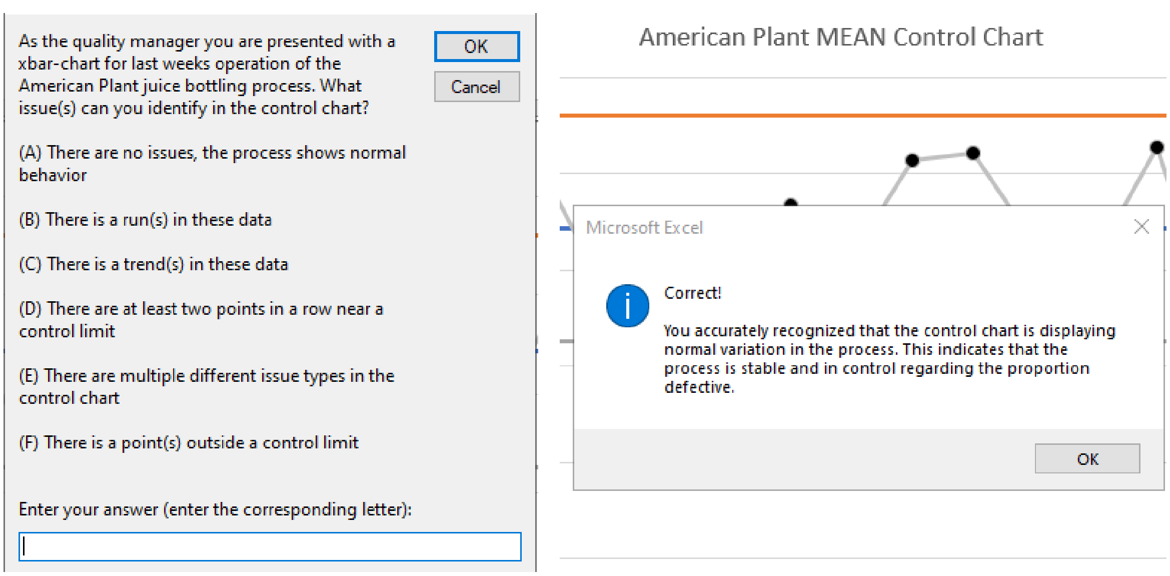
Selection of the "Plot Data on XX Chart," where XX is either the Mean, Range, or p, will generate the control chart similar to the example in Figure 10 and initiate a series of questions that must be answered by the learner.

FIGURE 10
Sample MEAN Control Chart for Scenario 1



When the learner has viewed the control chart, they will be asked to interpret the data. In Figure 10, the data indicates that on the MEAN chart, the process is in control, hence a selection of "(A) There are no issues, the process shows normal behavior," is correct as shown in Figure 11.

FIGURE 11
Sample MEAN Control Chart Interpretation



If the control chart exhibits any of the specified conditions other than the in-control condition, several follow-up questions will be generated. These follow-up questions are designed to put the learner in the position of a decision-maker to suggest specific actions to be taken in response to the condition. For example, if the learner has correctly recognized that "There is a trend(s) in these data," see Figure 12, the learner will see additional questions as shown in Figure 13. Feedback is given for both correct and incorrect answers as shown in Figure 14. Once the follow-up questions are answered correctly, the simulation will allow the learner to either explore the remaining control charts or move on to a different scenario.

FIGURE 12
Sample MEAN Control Chart with a trend

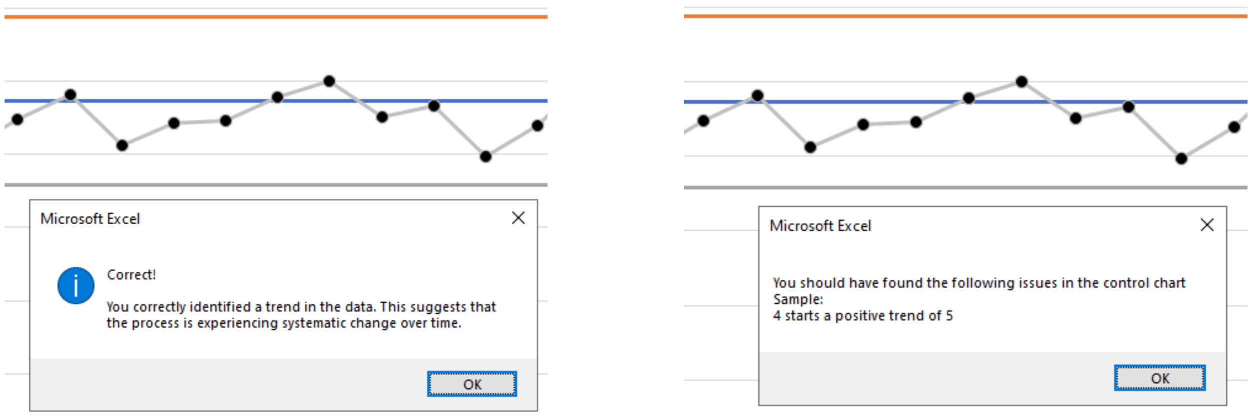


FIGURE 13
Sample MEAN Control Chart follow-up questions

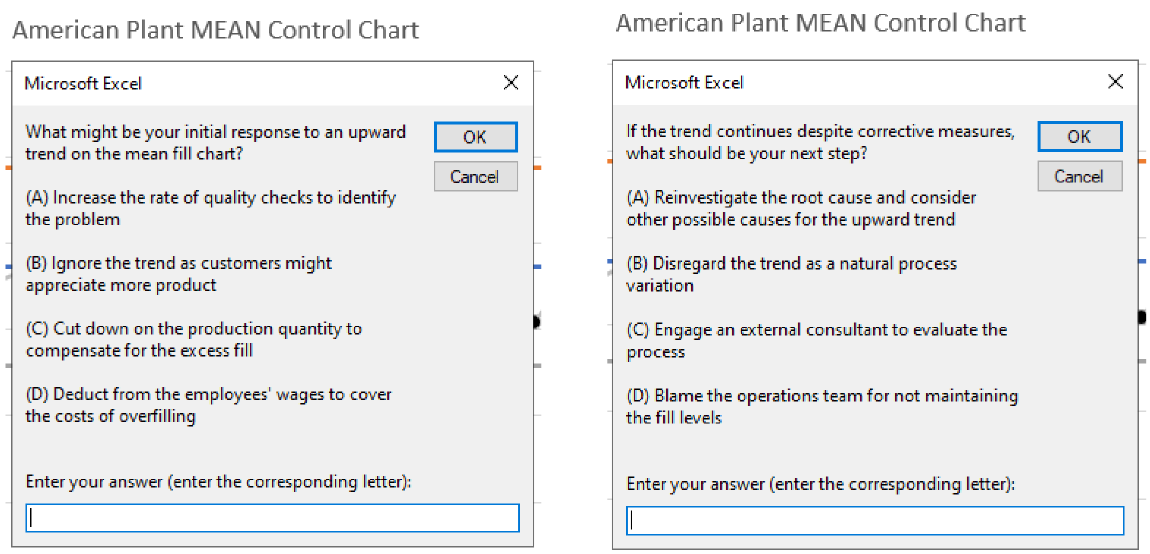
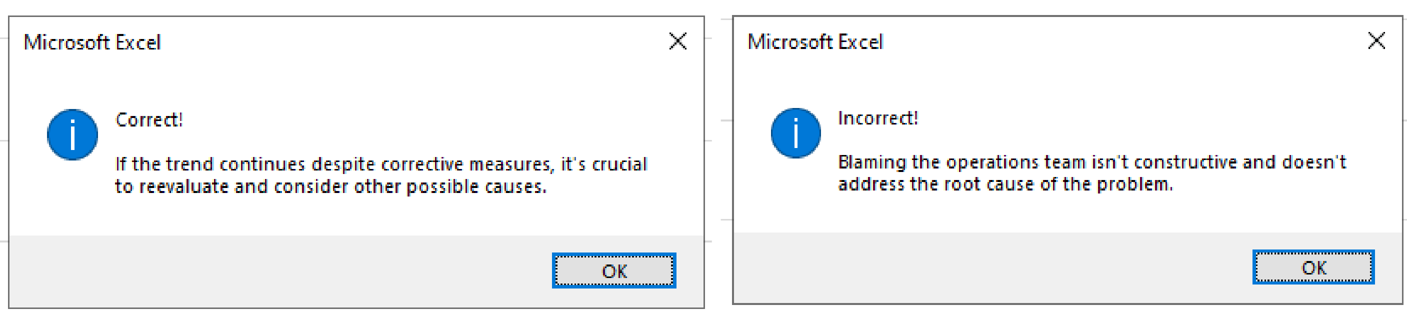


FIGURE 14
Sample MEAN Control Chart Feedback



The Juice SPC Challenge is complete when the instructor-assigned number of scenarios have been completed. A file containing a verification that the assigned number of scenarios have been completed successfully is automatically generated and can be submitted by the learner for grading purposes. However, the real power of this simulation is that it provides a sandbox for users to practice the key concepts of SPC. This practice comes from running the scenarios and answering the questions. The simulation contains over 150 unique questions, similar to those in Figure 13, which are randomly given to the students. Thus, each reset of the simulation and each learner will answer a unique subset of questions. Each simulation reset will generate unique data, so no two runs of the simulation will be the same.

STUDENT RESPONSE

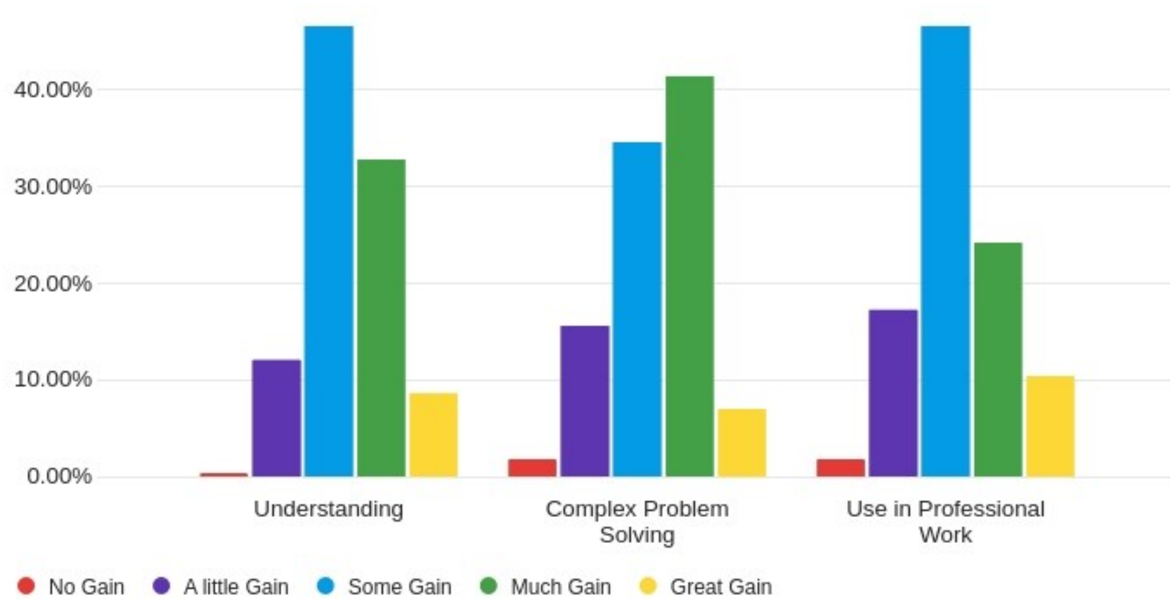
In nearly five decades of scholarly work, the Association for Business Simulation and Experiential Learning (ABSEL) has consistently advocated for the merits of experiential learning methodologies, emphasizing their impact on learning outcomes, attitudes, and behaviors (Anderson & Lawton, 2009). While the empirical rigor of these studies has been questioned (Girard, Ecalle, & Magnan, 2013; Gosen & Washbush, 2004), a comprehensive meta-analysis by Burch et al. (2019) identified 89 studies over 43 years that overwhelmingly supported the efficacy of experiential learning, with zero studies reporting negative outcomes.

Notwithstanding this empirical support, skepticism persists, often stemming from methodological limitations such as research design and measurement (Gosen & Washbush, 2004; Lewis & Williams, 1994; Wharton & Parry, 2003). The Kirkpatrick and Kirkpatrick (2006) taxonomy offers a structured framework for evaluating the impact of experiential learning, encompassing four levels: participant reaction, attitudinal shifts, behavioral changes, and organizational results. The majority of existing research, however, predominantly employs case study methodologies focused on the first level, rather than controlled experiments, looking at levels two through four (Leitão et al., 2021).

In this context, the Juice SPC Challenge was implemented in a foundational Operations Management course during the Fall term of 2023. Our evaluation focused on the first two levels of the Kirkpatrick and Kirkpatrick (2006) taxonomy: participant reaction and attitudinal changes. Post-challenge, an anonymous survey was administered to 66 students, utilizing a modified version of the Student Assessment of their Learning Gains (SALG) instrument, a validated and reliable tool for measuring perceived learning gains across various disciplines (Danko, 2020; Seymour, Wiese, Hunter, & Daffinrud, 2000). Fifty-nine students voluntarily participated in the survey, and one survey was removed due to incomplete data.

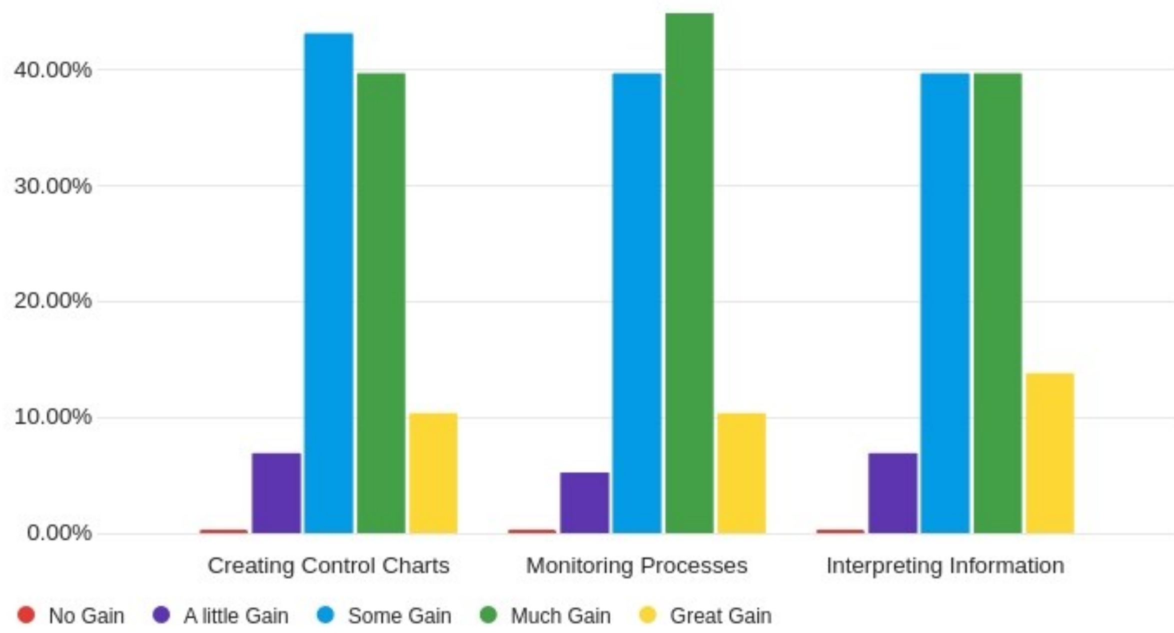
The findings from the 58 survey responses were unequivocal: students reported significant learning gains, most notably in the area of complex problem-solving, the middle bar in Figure 15, a core objective of the Operations Management curriculum. This data not only reinforces the pedagogical value of the Juice SPC Challenge but also contributes to the broader discourse on the efficacy of experiential learning methodologies.

FIGURE 15
Gains in confidence from the Juice SPC Challenge



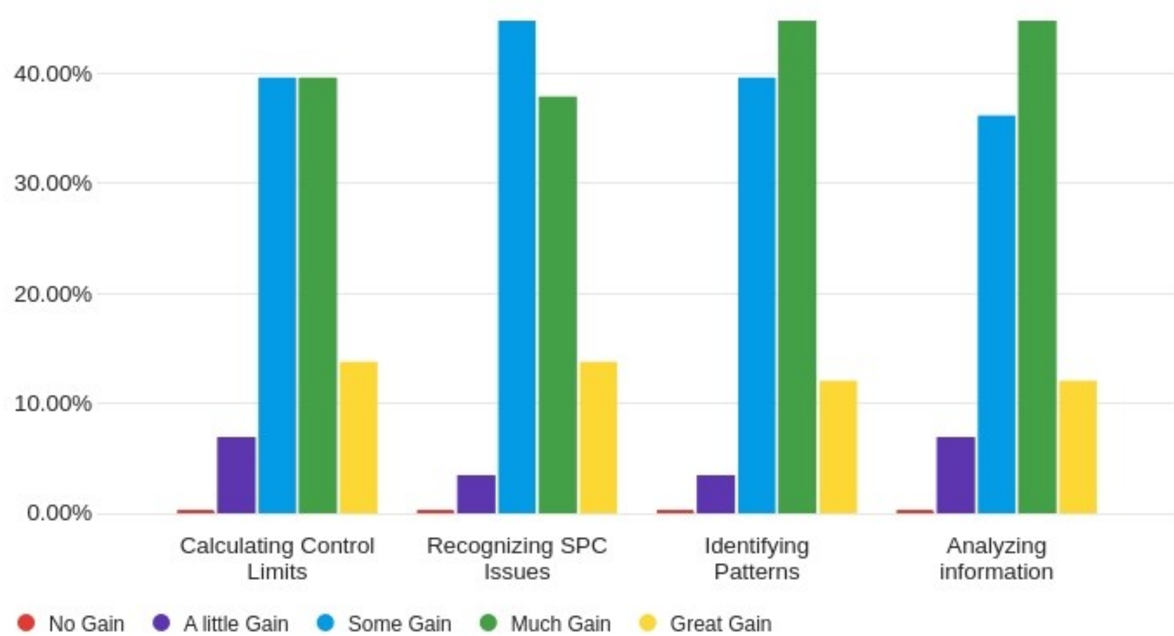
Regarding the Juice SPC Challenge objectives, students indicated that they gained skills in creating, monitoring, and interpreting control charts (Figure 16).

FIGURE 16
Gains in creating, monitoring, and interpreting skills from the Juice SPC Game



Specifically, skills in recognizing SPC issues were the greatest. This is an integrative skill that is challenging to communicate using a traditional lecture and textbook modality (Figure 17).

FIGURE 17
Gains in calculating, recognizing, identifying, and analyzing skills from the Juice SPC Challenge

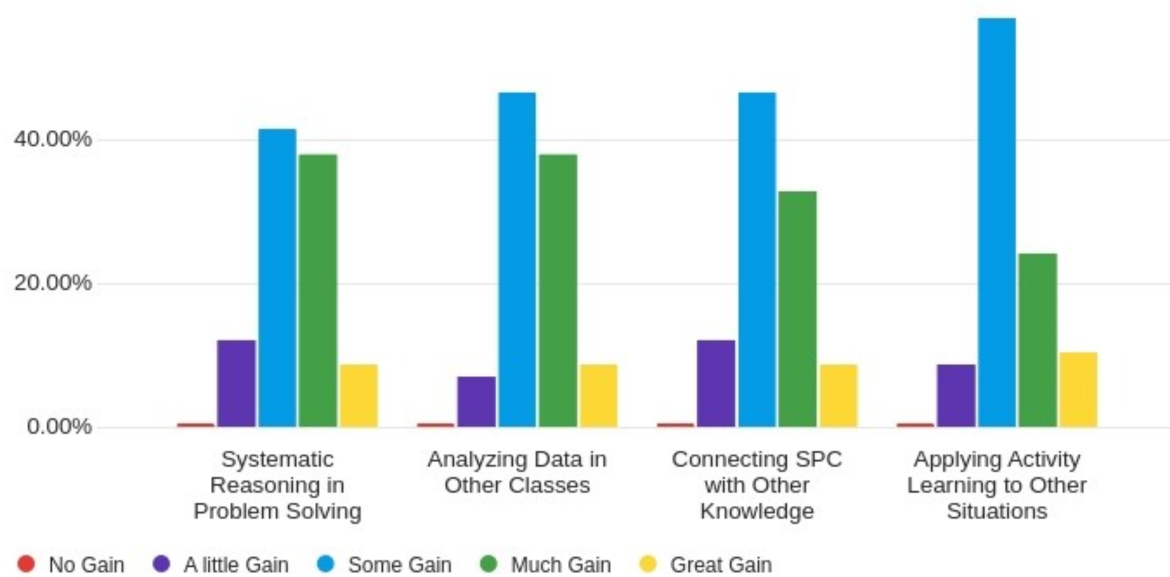


While students indicated some gain in enthusiasm for the SPC subject, they experienced greater gains in usefulness and connection to the real world (Figure 18).

FIGURE 18
Gains in attitude from the Juice SPC Challenge

Finally, integration and transfer of learning are the ultimate goals of education (Hajian, 2019). The data indicate that students recognized perceived gains along this dimension (Figure 19).

FIGURE 19
Gains in integration from the Juice SPC Game



DISCUSSION AND CONCLUSION

The introduction of the Juice SPC Challenge in Operations Management several critical issues that have been persistent concerns in traditional pedagogical approaches. The Juice SPC Challenge serves as an educational tool that not only enhances the learning experience beducation marks a significant advancement in the teaching of Statistical Process Control (SPC). We have addressed ut also prepares graduates for the complexities and demands of the modern job market. One of the most compelling pieces of evidence supporting the effectiveness of this simulation is the overwhelmingly positive response from learners. As indicated in Figures 20 and 21, a significant 33% of participants felt they learned "a lot" from the simulation, and an astounding 98% found it to be "somewhat valuable" or "valuable" to their education. These data underscore the effectiveness of the simulation in delivering a meaningful and impactful learning experience.

FIGURE 20
Juice SPC Challenge Learning Amount

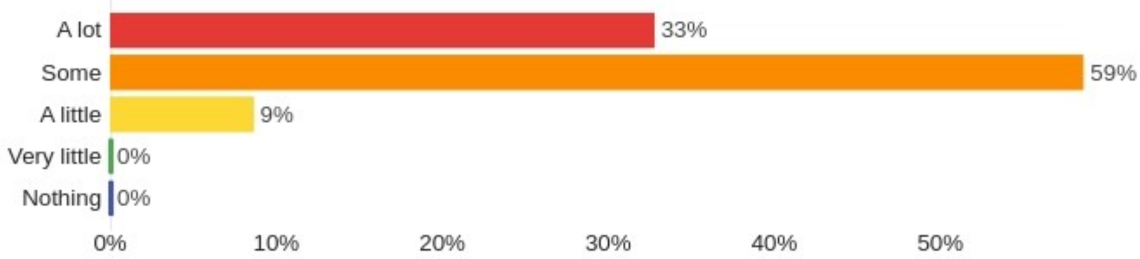
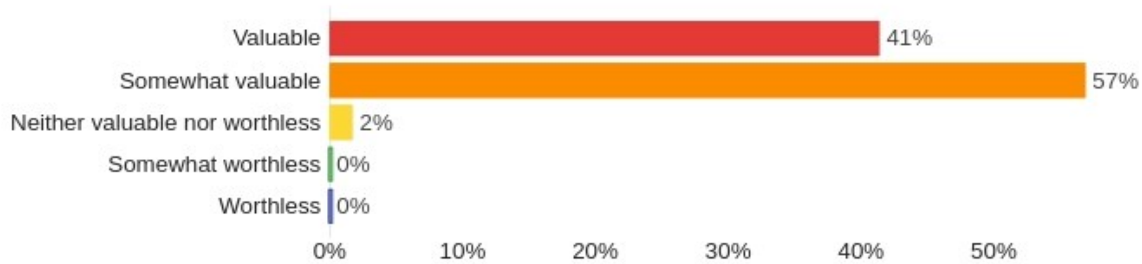


FIGURE 21
Juice SPC Challenge Education Value



Moreover, we identify specific areas where students often struggle in SPC, such as understanding when to create a control chart, distinguishing between sample size and the number of samples, and making decisions based on control chart data. The Juice SPC Challenge was explicitly designed to address these struggles. The simulation provides immediate feedback on SPC decisions, a feature not possible with traditional textbook problems. This immediate feedback is crucial for reinforcing learning and improving understanding. The simulation goes beyond mere knowledge acquisition; it fosters the development of higher-order cognitive skills. By engaging students cognitively, the simulation allows them to explore, experiment, and make decisions in a controlled environment. This active learning approach is essential for the development of critical thinking and problem-solving skills, which are not only academically beneficial but also crucial for professional success.

Furthermore, the simulation's alignment with the evolving needs of the industry is another significant contribution of our simulation. By providing a realistic setting for the application of SPC techniques, the Juice SPC Challenge prepares students for the challenges they will face in their professional careers. This alignment enhances the employability of graduates, making the education more attuned to market demands. As the field of SPC education continues to adapt and evolve, the Juice SPC Challenge promises to be a valuable asset in shaping future pedagogical strategies. The simulation's integration into SPC education is supported by a wide array of academic research, making it a timely and relevant addition to the discourse on effective educational strategies in this field.

Was the Juice SPC Challenge successful in meeting its objectives and providing a contextual learning experience? Preliminary evidence from the SALG survey suggests that the simulation is indeed valuable. Students reported gains in skills, understanding, and the practical application of Statistical Process Control concepts. As the Juice SPC Challenge was first implemented in the fall of 2023 and is still under development, a comprehensive comparative study remains a subject for future research. Nonetheless, initial observations suggest that the simulation offers a meaningful improvement over traditional teaching methods.

Operations Management is a complex subject that demands critical thinking and mathematical problem-solving skills. Many students struggle with it because they don't see its relevance to their lives (Miyaoka et al., 2018). However, motivation increases when students find value in what they are learning (Johnson, 1996). The SALG survey data indicates an increase in the perceived usefulness of SPC concepts, suggesting that students are more motivated and likely to retain the knowledge gained.

In summary, the Juice SPC Challenge serves as a significant advancement in the educational landscape of Operations Management. It addresses the limitations of traditional teaching methods, aligns with current research and industry needs, and prepares students for real-world applications. The overwhelmingly positive response from learners attests to the simulation's effectiveness and its potential to improve how SPC concepts are taught.

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APPENDIX A
Instructions for the SPC Control Game 2023

Task 1: Set up (CREATE) control charts from the Netherlands bottling plant process

1. Open the SPC Control Game (version 2.00).xlsb (use the search function on the windows toolbar)
2. The simulation will ask for a password – enter "student"
3. The simulation is navigated by Excel tabs located at the bottom of the screen – The opening screen is the "Netherland Plant" tab. The other visible tab contains the "Factor Table" needed to calculate the control limits.
4. The simulation should already be reset, however, if needed, you can click on the "Reset Simulation" button.
5. Click on the "Simulation Setup" button
   - α. A popup allows you to change the Sample Size and Number of Samples – the default of 25 and 20 respectively, is acceptable.
   - β. After these values are set, click on "OK"
   - χ. The simulation will run, showing the desired number of samples with the indicated sample size. All the data necessary to calculate values along the top of the screen will be generated by the simulation.
6. Calculate the ten (10) values needed to create the control charts, found in the orange boxes along the top of the screen (round to three digits after the decimal e.g., 0.000)
   - α. The check mark next to the orange input box can be used to check your answer.
   - β. Use the "Create Summary Data" button to copy the data needed for your calculations to the clipboard. You may copy these data to a new spreadsheet to perform calculations in Excel.
7. To view the actual control charts generated by the simulation samples for the Netherland Plant, click on the related button.
   - α. "Create Mean Chart" will generate the mean control chart for the data in a new tab at the bottom of the screen. Select the "Netherland Plant" tab to return to choose other options. (available when control chart information has been calculated and entered correctly)
   - β. "Create Range Chart" will generate the range control chart for the data in a new tab at the bottom of the screen. Select the "Netherland Plant" tab to return to choose other options. (available when control chart information has been calculated and entered correctly)
   - χ. "Create p Chart" will generate the p control chart for the data in a new tab at the bottom of the screen. Select the "Netherland Plant" tab to return to choose other options. (available when control chart information has been calculated and entered correctly)
8. Once you fully understand the creation of control charts (and all answers are correct), you will be given a button to "OPEN AMERICAN FRANCHISE" and to continue the simulation. If everything is ready, a popup will let you open the American Plant, a new tab will be created called "American Plant", and that tab will be activated.

Task 2: Check (MONITOR & INTERPRET) the new American Plant process data for control

1. On the "American Plant" tab, you will be presented with another simulation.
2. Click on the "Simulation Setup" button.
   - A popup allows you to change the Number of Samples – the default is the same as was used in the Netherland Plant and can be left at the default values.
   - After these values are set, click on "OK"
   - The simulation will be run for a specific scenario. Select a scenario from the drop down menu under the "Run Simulation Scenario Selected BELOW" button.
   - While any scenario may be selected you are required to select 15 different scenarios to complete the assignment (you may run all 24 if you wish). Once selected press the "Run Simulation Scenario Selected BELOW" button.
3. The American Plant data collected can be plotted on the control charts (created from the Netherland Plant data/ calculations) using the related buttons
   - α. "Create Mean Chart" will plot the American Plant data on the mean control chart in a new tab at the bottom of the screen, "AP Mean Control Chart".
     - i. On the Mean Control Chart select the continue button and you will be given some questions regarding the control chart.
     - ii. Complete all questions for the control chart and then move on to the next control chart.
   - β. "Create Range Chart" will plot the American Plant data on the range control chart in a new tab at the bottom of the screen, "AP Range Control Chart".

i. On the Range Control Chart select the continue button and you will be given some questions regarding the control chart.
ii. Complete all questions for the control chart and then move on to the next control chart.

c. "Create p Chart" will plot the American Plant data on the p control chart in a new tab at the bottom of the screen, "AP p Control Chart".

i. On the p Control Chart select the continue button and you will be given some questions regarding the control chart.
ii. Complete all questions for the control chart and then move on to the next control chart.

d. After all questions have been answered for the scenario selected, select a new scenario and repeat the process of reviewing the generated control charts.

Task 3: Submit the file to show completion of the assignment

After completing all of your selected scenarios, you will find a file named "Simulation Results.xlsx" on your desktop. This file just contains numbers and is not something you need to edit. It tells me what happened during the simulation and if you completed the simulation.

NOTES:

Don't alter the "Simulation Results.xlsx" file. The scenarios are unique for every student. So don't submit another student's file. This is a violation of academic integrity as indicated in the syllabus.