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The problem-solving workshop: adapting process improvement methodologies for K-12 educators

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The Problem-Solving Workshop: Adapting Process Improvement Methodologies for K-12 Educators

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Abstract

Lean and Six Sigma have been lauded in the manufacturing sector for their ability to streamline processes, reduce waste, minimize variation and defects, and improve the bottom line. Although these methodologies have begun to spread to other industries, their impact has been relegated to certain areas and has largely missed others. One area that bears strong consideration is education. Education is heavily process-based and notoriously tight on resources. It is hypothesized that if educators were taught the basics of these strategies and were able to implement them in the classroom setting, the effectiveness of both teaching strategies and classroom operations would improve, saving teachers time and improving school performance in a number of areas. This study focused on developing and testing a workshop-based method for teaching the process improvement methods to K-12 teachers and administrators with the goal of finding a method that could be scaled. Engagement emerged as a significant obstacle, but based the workshop results and feedback from educators, the study found that overall, the workshop is a viable method for communicating these skills. Alternate ideas for future programs are presented based on the challenges encountered with the pilot study.

Keywords: Six Sigma, Lean, process improvement, K-12 education, engineering management, problem solving, workshop, engagement

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Introduction

Beginning in the 1980s, the world of manufacturing underwent a revolution. The revolution encompassed an industry-wide shift to a focus on quality and process improvement. Two of the methodologies that rose above the rest during this period and continue to impact the world today are Lean and Six Sigma.

The overarching idea of Lean is waste reduction— waste being anything that requires resources but doesn't create additional value (Womack, 1996, pp. 15). As Womack and Jones (1996), who popularized Lean with their book *The Machine That Changed the World* say, "[Lean] provides a way to do more and more with less and less" (pp.15). When the Toyota Motor Corporation of Japan was faced with relatively small demand and lack of capital, especially when compared to giants like Ford, they had to find a new way to produce automobiles efficiently. Their focus on waste reduction and value turned into the Toyota Production System, which remained largely within Toyota's supply chain until the recession in 1973, when the speed with which the company bounced back relative to other companies garnered widespread attention (Liker, 2004, pp. 24). The tools and principles they used became the foundation for the methodology that would later become known as Lean.

Six Sigma stemmed from some of the same guiding principles that were used by Toyota, but it became a distinct methodology when it was used by Motorola in the 1980s (The Council for Six Sigma Certification). Six Sigma is based on statistical analysis, and the name "Six Sigma" comes from the standard deviations (represented by the Greek letter sigma, σ) in a normal distribution. At six standard deviations, 99.999% of the data is within the acceptable range (The Council for Six Sigma Certification), whether it be a range of rate of failure, variation in quality, etc. This encapsulates one of the main goals of Six Sigma— to reduce variation and/or

defect to the point where it is almost nonexistent. Six Sigma makes use of methodologies like DMAIC (Define-Measure-Analyze-Verify-Control), a data-driven step-by-step process of problem solving. While both of these methodologies began in manufacturing, there is evidence that methodologies like this have been successfully applied across the board, and notably for this study, in education (Simons, 2013).

Most of the work that has been done in education with Six Sigma and Lean is related to higher education. This paper argues that primary and secondary schools may present an even greater opportunity to create due to their ubiquity and hierarchical nature. Even so, the notion of applying process improvement principles to K-12 education is not an entirely new idea. In Menomonee Falls, Wisconsin, Superintendent Pat Greco turned a district that "had one of the highest suspension rates in the region", inequality, and failing standards into one that had a 98% graduation rate and one-third the amount of previous suspensions by utilizing continuous improvement methods (Baron, 2017). In Adams County, Colorado, Assistant Principal Brian Hodges led a project team that used Six Sigma tools to successfully address an air quality issue that was affecting the health and attendance of students (LeMahieu, 2017). In Aiken County, South Carolina, the district used Six Sigma to make strategic plans to conserve energy and save costs (LeMahieu, 2017).

Although not specifically aligned with Lean and Six Sigma, there have also been programs aimed at improving education through quality (quality being used here in a technical sense: an increased attention to and measurement of current performance compared to the standards of expected performance) and continuous improvement. Perhaps the largest scale program to address quality in schools was Koalaty Kid. A program started in the 1980s, that was later absorbed by ASQ (The American Society for Quality), Koalaty Kid drew attention to the

quality of work students were doing and encouraged them to make a conscious effort to improve, using metrics to measure their progress (Smith, 2002). This method improved student reading levels and later on, scores in other areas like mathematics (Smith, 2002).

Specifically educating faculty has also been approached; in an article for the ASQ Primary and Secondary Education Brief, mathematics and operations management professor Leslie Gardner describes the workshops she holds for teachers as an introduction to supply chain management (Gardner, 2012). Gray Reinhart wrote a book called *Quality Education* that introduced quality as it was used in an industrial sense for educators and provided tips on integrating it into their classrooms (Reinhart, 1993). All of these occurrences show that there is value and potential to the concept of applying process improvement principles to K-12 education, but despite the success these schools and individuals have had, the use of manufacturing and process improvement principles in schools is not common. There is a lack of a path forward for schools that would allow them to easily adopt these principles. The goal of this study was to find a way to increase the range of schools that have access to these process improvement principles by developing a method to teach administrators and teachers how to implement them.

Methodology

Traditionally, those who want to learn about Six Sigma or Lean attend certification classes either in person or online. Training courses cost anywhere from a few hundred to $5000, with the average being around $2500. These courses are either condensed into a few intense days or spread out over six to eight weeks.

It was assumed for this study, based on basic knowledge of the education system and current events (notably the teacher strikes in 2018, contributing to the largest number of striking workers since 1985 (Van Dam, 2019) for which one of the major driving factors was the underpayment of teacher salaries (Wolf, 2019)) that time and money are two significant pain points for educators. Therefore, the method for teaching these tools would have to incur minimal cost and time to be effective.

Based on these factors, it was decided that the best form of instruction would be a series of workshops held through the UTC Department of Engineering Management & Technology. Benefits provided to educators were seen as the following: free professional development, continuing education/professional development credit, and the opportunity to improve their classrooms/schools and increase their productive time.

Workshop Development

The workshop was divided into three parts to provide flexibility for educators and to provide greater exposure to the tools and information. The first part of the workshop would be a three-hour informational session. Three hours was determined based on previous courses and trainings as the maximum amount of time a potential participant could be asked to block off without it becoming a significant deterrent to their participation. This session, led by two

workshop directors certified in Six Sigma, would be used to teach the fundamentals of Lean and Six Sigma as well as introduce key tools that educators could use. The second session did not include any formal meetings and would occur over two months. During this time, educators would be asked to use the tools they had learned to identify potential problems in their schools and classrooms and take preliminary measurements (e.g., number of students late to class, time students spent waiting in lunch line as opposed to eating during lunch, etc.). Workshop directors would check in every two weeks to answer questions and monitor progress. This stage would give participants a chance to practice their skills while still having access to mentors. The third part of the workshop would consist of a 3-hour problem solving session in which educators would meet with workshop directors and other process improvement specialists (Certified Six Sigma Green Belts, likely from UTC Engineering Management & Technology faculty) to go over the problems they had discovered and walk through the rest of the problem solving process. Educators would be encouraged to participate in all three sessions, but able to participate selectively as their schedule required. All sessions would be offered free of charge. (This study was funded by a SEARCH grant from the University of Tennessee at Chattanooga.)

After initial development, focus shifted to the first of the workshops, the instructional workshop. The immediate challenge of this study was to condense instructional material typically taught over approximately sixteen hours into three.

Content

In order to have the skills necessary to develop and administer the workshop, both workshop directors (the author and faculty advisor) became certified through the American Society for Quality (ASQ) via exam certification. The author became a Certified Six Sigma Yellow Belt (September 2019), and the faculty advisor became a Certified Six Sigma Green Belt

(October 2019). The content and body of knowledge for these exams was used as the basis for the instructional workshop session.

The following topics were covered in the workshop session:

- Overview of Six Sigma
- Overview of Lean
- Teams
- Overview of DMAIC process
- Define Phase
    - Brainstorming
    - Affinity Diagrams
    - Process Flowcharts
    - Fishbone Diagram
    - Why-why Diagram
    - Check Sheets
    - Scatter Charts
    - Pareto Charts
    - Tools in Excel Demo
- Measure Phase
    - Check Sheets
    - Surveys
    - Interviews

The material for the session was divided into three main sections: background information, process, and tools. The background information portion consisted of a basic overview of Lean and Six Sigma. The process portion introduced participants to DMAIC, which is a data driven process improvement cycle commonly used in Six Sigma. The tools portion introduced the participants to nine common tools used at different points in the DMAIC process.

The end goal of the workshop was that educators would have a basic familiarity and moderate confidence in using the tools covered in their classrooms. Because of this, background information on Lean and Six Sigma was kept to a minimum. This is compared to introductory Six Sigma courses, which can, in some cases, be up to 20% background information and history (The Council for Six Sigma). The reasoning was that much of the history of Lean and Six Sigma

is rooted in manufacturing, and rather than helping with understanding, this would alienate the tools to educators and distance them even more from their use in education. The explanations of Lean and Six Sigma as they are included in this presentation are meant to provide a backdrop for the information learned and introduce the idea of continuous improvement and minimizing waste.

The DMAIC (Define-Measure-Analyze-Improve-Control) process was identified as being the key component of the problem-solving process. Part of the reason why Six Sigma is so successful is because the DMAIC process gives users a step-by-step guide to follow, ensuring that each decision is methodical and backed by data. This was one of the key takeaways that the workshop was designed to impart. The plan was to cover the first two phases, Define and Measure, and touch briefly on Analyze. These would later be practiced in stage 2 of the workshop series.

Most of the tools included in the following section were those that would be used in the Define and Measure phases, although it was recognized that many of the tools were not bound to any one stage. For example, brainstorming can be used to help define the problem, but also later in the process to help generate alternative solutions in Improve. The tools were selected based on the following criteria: wide range of application, low level of complexity, and ease of use. The study tried to combine semi-familiar topics such as brainstorming and check sheets with lesser known tools like the fishbone diagram. The goal was to have educators widen their perspectives and identify issues (**brainstorming**), be able to organize those thoughts (**affinity diagrams**), examine current processes they were using (**process flow diagrams**), collect data to determine what issues were actionable problems (**check sheets**), get to the root of those problems (**fishbone**

and why-why diagrams), and analyze the data inform future decisions (**scatter chart, pareto chart, and Excel tools**).

For many of the tools, standard examples from industry or textbooks were not suitable or applicable to the workshop, so new examples were created based on either school problems or personal examples that were more relatable. An Excel demonstration was included to teach basic statistical analysis, show the process from check sheet to graphical form (pareto/scatter chart), and provide a quick and easy method for data visualization.

It was decided that the workshop should include a supplementary material so that the teachers and administrators would have a guide to return to and something to reference during the second part of the workshop. *The Memory Jogger: A Pocket Guide of Tools for Continuous Improvement* was selected as a concise and cost-effective way to provide the reference guide desired. Seven of the nine tools covered were included in the guide, and this was incorporated into the presentation with reference page numbers. Other resources that contained more tools like *The Lean Six Sigma Pocket Toolbook* (George et al., 2004) were considered, but it was decided that participants would likely be overwhelmed by the overabundance of information and would be more likely to use the former resource.

Methods of Measurement

In order to track the participants' process and the effectiveness of the workshop elements, two surveys were created. The first was labeled a "milestone survey", intended to be used as a benchmark that progress could be measured against throughout the three workshop sessions. This survey (Appendix C, Milestone Survey) would be administered four times: 1) before the

initial workshop session, 2) after the initial workshop session, 3) after the two-month second workshop, and 4) after the problem-solving session.

A second survey (Appendix C, Post-Workshop Survey) was created specifically for the instructional session. This survey was more qualitative in nature and was aimed at capturing participants' perspectives on how the workshop was run and the material was delivered. While the other survey measured effectiveness of teaching, this survey was intended to measure participant engagement and buy-in.

Promotion

As previously noted, one of the key components to this workshop was making it accessible to educators. Hamilton County, TN was selected as the participant pool, due to geographic convenience.

In order to provide additional incentive for participation in the workshop series, the workshop directors collaborated with Hamilton County's Chief Schools Officer to offer the series for professional development or continuing education credit. Educators would be given a certificate after completing the workshop session(s), and that certificate would be uploaded through Hamilton County to receive credit. The certificate was designed by the College of Engineering and Computer Science's graphic designer and provided by the workshop directors. The series was slated for a total of ten credit hours: three for the instruction session, four for the second session taking place over two months, and three for the final problem-solving session.

The workshop was primarily promoted by word of mouth and email. A promotional flyer (Appendix B) was created and attached to all promotional emails that were sent out as well as handed out during a school counselor luncheon event held at the College of Engineering and

Computer Science. Researchers used email lists provided by the College of Engineering and Computer Science outreach coordinator. These lists were a compilation of the email addresses of all educators who had previously attended an event held at or sponsored by the College of Engineering and Computer Science. Additional emails were added via community connections or suggestions. Approximately 100 emails were sent out to educators in the Hamilton County area and surrounding counties. From these, seven replies were received. Four of those who replied went on to register for the workshop session.

An article was published in the UTC News Releases blog in the week leading up to the workshop (UTC Marketing and Communications, 2019). No additional participants reached out after the publishing of this article. Analytics for this article were not able to be tracked. However, a reposting of the article on the networking site LinkedIn received 410 views between October and January.

Pre-Workshop Set Up

In an effort to increase engagement and form a community between participants, a Slack workspace was set up. Slack, a cloud-based instant messaging platform and collaborative workplace software created in 2013 by Slack Technologies, allows users to create a workspace (often the company or organization) and channels within that workspace. Key features of Slack include direct messaging, channel messaging/posting, and file sharing. A week and a half prior to the workshop, information was sent out to participants via email introducing Slack and explaining the purpose to which it would be put for the workshop. A link was provided to create an account and join the workspace. Three of the four participants joined the platform.

One week prior to the workshop, each registered participant received an email with 1) location and time, 2) parking instructions and an annotated map, 3) a Six Sigma in education success story designed to stimulate interest in the topic (Ruff, n.d.), 4) what to bring/what the workshop would be providing, 5) a reminder on how to join Slack and a link to the workspace, and 6) the planned agenda for the workshop. This information was also posted in the general channel of the Slack workspace.

Workshop Session I

Once participants arrived in the session space, they were asked to sign in, listing their name, preferred method of contact, and school/organization affiliation. Each participant was given a folder with two milestone surveys, the post-session survey, a legal pad, the *Memory Jogger*, and a pen. Sticky notes, highlighters, and other materials were provided. Participants were provided with refreshments and encouraged to get to know other participants. During this time, the workshop directors asked that participants fill out the first milestone survey before the workshop began and set it aside. Each survey was anonymously numbered so that results from subsequent surveys could be compared. The main body of the workshop consisted of a PowerPoint presentation (See Appendix A), with a break for lunch and discussion. After the information session was complete, participants were given info about the second part of the workshop, along with additional resources and contact information.

At the conclusion of the session, participants were asked to fill out the second milestone survey and the post-session survey. Once this was finished, each participant was given a sheet that listed the participant's name and a statement that they had attended the workshop for three hour's credit. The sheet was signed by both workshop directors and was intended as a placeholder until the final certificates were awarded at the end of the series if the participant

chose to continue. Each participant affirmed that they would be continuing with the workshops. After the session, each participant received a follow up email with a copy of the presentation and an Excel file with a completed version of the Excel demonstration for future reference. The demonstration file included text instructions for creating each type of diagram from the check sheet data.

Workshop Session II

Articles and check-ins were posted through Slack on a weekly basis. The articles covered topics like Lean education, step-by-step writing of problem statements, and a review of the 7 wastes. For four weeks after the problem-solving workshop, participants were sent an email each week. Initial emails asked about any progress the educators had made in defining problems. Subsequent emails asked educators if they could think of any problems that they or other educators were facing. There was a 0% response to all communication. After multiple attempts at email communication, calls were made to each school, and all calls were unreturned.

Post-Sessions

After the second stage of the workshop, the project was reevaluated by the workshop team. It was decided that the third portion of the workshop could not be carried out with the current lack of participation. Participants were sent their certifications for completing the first workshop session and the focus shifted to analyzing the learnings from the initial workshop and gathering informal feedback from educators. This was used to inform potential future versions of this workshop, found in the recommendations section of this paper.

Current and retired teachers were consulted and interviewed on an informal basis in an effort to discover underlying issues that may have affected the workshop’s success and general

attitudes towards educational and professional programming. These conversations revealed a focus in three primary areas: frustration with diminished instructional time, expending of personal resources for students, and a disconnect with administration.

Analysis

Primary area for analysis from the instructional session included survey results and observations from the workshop. The milestone survey, although intended primarily for improvement over the entire series, did show that as a whole, the participants felt that they were more confident in using the tools that were highlighted in the workshop. In the pre-workshop milestone survey, the participants were asked how confident they felt using the nine tools the workshop would cover that day. The participants chose 1, or "Not confident" 64% percent of the time, and 5, or "Very confident", only 14% percent of the time. In the milestone survey taken after the workshop session, the participants chose "Very confident" in using those tools 53% of the time. As shown in the graph below, there is a strong shift toward confidence after the workshop, indicating that the objective of increasing educator confidence in using the tools was successful.

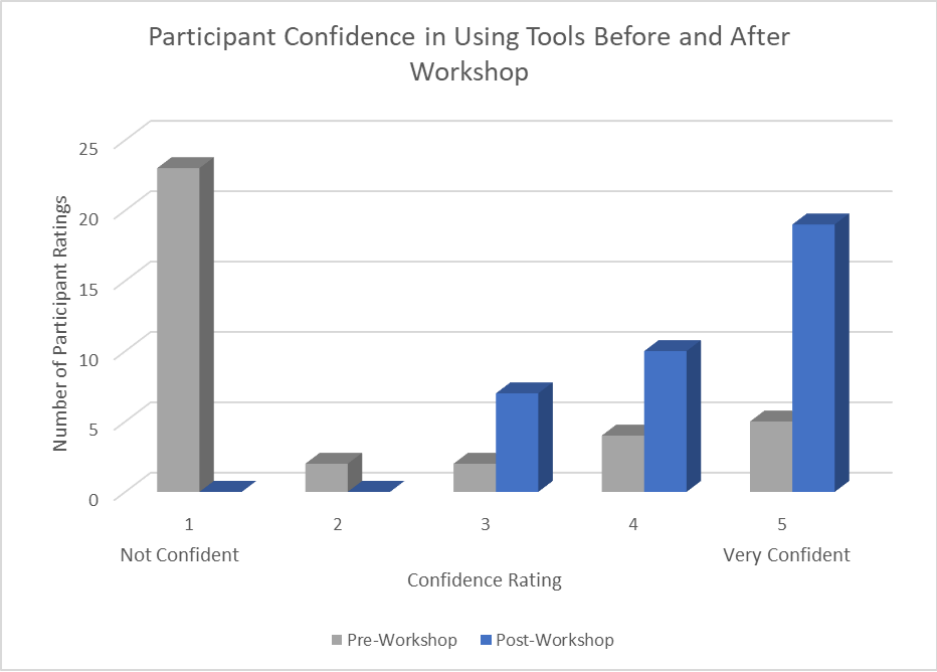

Image 1: Participant Confidence in Using Tools Before and After Workshop

The qualitative post-workshop survey results, compiled in Appendix C, show that educators were pleased with the workshop overall. All of the participants reported that they would “highly recommend” this workshop to other teachers and administrators. 3 of 4 of participants reported the workshop as “very helpful”. The qualitative responses show a similar level of satisfaction. It appeared that the one area that could have been improved was by giving participants an opportunity to practice the tools.

During the workshop, participants appeared to be engaged. They frequently asked questions or inserted commentary (approximately once per every three slides), and discussions that began with one question were often expanded to other participants. Participants seemed comfortable in the space, with each other, and with the workshop directors.

This contrasts sharply with the lack of communication and participation during the second stage of the workshop. Unfortunately, there was no feedback that could be used to determine the reason for this drop in participation, but based on the results from the previous session and informal interviews held with other teachers, tentative conclusions can be drawn. Looking at the potential reasons for a lack of engagement, it is hypothesized that these reasons also came into effect, and having already received the “benefit” (learning the skills), educators had less drive to continue to pursue the series.

Structural Factors

The idea of upper management support being crucial to projects and programs is a thread that runs through quality, process improvement, and general management. W. Edward Deming, a prominent engineer and leader in the quality movement, stressed the importance of upper management support and leadership when creating an environment of continuous improvement.

Although the district "supported" the workshop by agreeing to offer credit for it, there was no real push from the administration or the district to encourage educators to participate.

These theories are supported by the successful case studies mentioned in the introduction. In the case study that was used in the workshop, it is stated that Brian Hodges was hired by the administration to conduct process improvement studies (Ruff, n.d.). Pat Greco represented upper management (Baron, 2017), and Aiken County was a district-wide effort (LeMahieu, 2017). The failure of this workshop to meet that criteria was likely a critical factor in teacher involvement. A study by M.L. Emiliani (2015) looked into integrating Lean teaching into higher education. Emiliani (2015) comments that change in the school system is a "shared responsibility" between faculty and administration, and that "the prospects for success are low if approached from the bottom-up, with faculty appealing to leadership" (pp. 2). This lends itself to explaining the lack of participation in the second workshop session; even with very engaged educators, enthusiasm alone was not enough to create a significant impact without upper management support.

There was also a lack of champions, people "on the inside" of the organization who have or able to make meaningful connection and encourage others to participate by communicating the value of the activity. While this project was able to reach a small number of interested educators, there was no driving force to push engagement within schools.

Another factor is the notion of mandatory participation. Often, constraints due to lack of time can be overcome by a mandatory requirement. In this case of this study, because there was no requirement and no consequence, the desire to participate would have to be strong enough to overcome the pressure from the time constraint, which was already known to be significant. Based on the workshop outcome, it was not sufficient for the majority of teachers who were

approached, and for the teachers who participated in the first session, it was not sufficient to ensure further participation.

This study was compared to a similar educational program launched by the University of Tennessee Knoxville's Tickle College of Engineering. This program leveraged a connection with a member of the district to make the workshop a mandatory event on an in-service day. The workshop was reported to be well-attended and successful. This supported several of the theories touched on in this section, as the program had upper management support, a champion, and a mandatory component. Future collaboration based on this program can be found in the future directions section of this paper.

Content-Based Factors

It is hypothesized that another reason our workshop fell short on engagement was because the problems the workshop focused on were not the pain points for teachers. Six Sigma is focused on improving the bottom line; proposals are ranked by their ability to generate profit or reduce costs. The workshop targeted several operational aspects of schools, like bus efficiency and class scheduling, but these are not necessarily problems that the average teacher cares about. The issues that they did care about, based on informal interviews, focused on lack of sufficient instructional time, lack of support and connection with administration, and the lack of resources to support their students. From a process improvement perspective, many of these areas could be targeted with Lean and Six Sigma strategies. However, our study chose to draw parallels where the correlation between manufacturing and school operations was the strongest.

In this study, schools were treated more as manufacturing than true service industries, because it was easier to formulate examples and explain concepts this way. The researchers

hypothesize that classifying public schools as service industries for this study and others would have led to a more applicable and relatable approach for participants. This is supported by the Unified Services Theory.

The Unified Services Theory, stated by Scott Sampson in “The Unified Services Theory Approach to Service Operations Management”, says that “With services, the customer provides significant inputs into the production process. With manufacturing, groups of customers may contribute ideas to the design of the product, however, individual customers' only part in the actual process is to select and consume the output” (Sampson, 2001). In education, the customers, primarily students, provide a great deal of input into the process. One could almost argue that the students themselves are one of the inputs. If the school as a whole is considered, it is the educators who provide many of the inputs for the process. In treating public education like a manufacturing operation, one misses a crucial aspect and the governing purpose.

There is also an issue in the fact that one must understand the basics of Lean, Six Sigma and process improvement to conceptualize the benefits they can produce; therefore, one must be enrolled in the workshop to see the value of the workshop, which makes initial interest very small. This highlights the need for champions within the population and a stronger promotional effort.

Overall, it appears that even though educators may find the workshop material interesting and pertinent, it is likely difficult to justify when they have many other tasks at hand and do not find the benefits compelling enough to their current situation. That lack of a compelling reason is partially due to a failure to separate Lean and Six Sigma enough from their manufacturing roots and apply them to issues that educators truly cared about. Other programs have compensated for

this lack of interest through structural means via mandatory programming and grassroots and administrative support.

Limitations

The limited participation in the study meant that the participant pool was very small, and conclusions drawn may not be representative of the whole. The educators present exhibited an interest in problem solving, which likely contributed to their willingness to participate, and all had some connection to a STEM background, likely due to the email list from which we drew their names. This may have produced skewed results that are not representative of other areas of focus, such as the humanities.

Additionally, survey questions were aimed at identifying the changes in the educators' understanding of the tools over time, and although some change was recorded over the course of the workshop, long-term change could not be accurately measured or included in the analysis.

Conclusions

Although the participant pool was small, the survey results and feedback from the workshop session were positive and supported the claim that a workshop would be an effective and efficient way to introduce educators to the Lean and Six Sigma methodologies and tools. Key results included the positive visual shift in confidence levels concerning the use of tools, a high rating on the helpfulness scale (an average of 9.25 /10, with 10 indicating that the participant found the workshop "very helpful"), and a high recommendation rate, with 100% of participants saying they would "highly recommend" the workshop to other teachers and administrators. There was not enough data to definitively say that a similar workshop would be a success, but the data from this study combined with other case studies builds a solid case for this method of instruction, provided that measures are taken to overcome the challenges seen here.

This workshop series revealed that the most significant obstacle to overcome was a lack of engagement. This study anticipated that barrier and included measures to draw in educators based on educator feedback. However, it became evident during the second stage of the workshop that engagement based on remuneration would not be sufficient. Future workshops should a) have the support of administration and the district, b) be required or heavily encouraged, and c) show a clear path to issues that educators care about. Educators prove time and time again that they are willing to go above and beyond for their students. This makes them excellent candidates to use the principles of Lean and Six Sigma, provided that the incentive is aligned with their true needs (the pain points discussed earlier). This workshop showed that there is interest in learning these tools and techniques and that educators see how they can be used in the classroom. However, there needs to significant support from within the organization to make this happen.

Recommendations and Future Direction

Based on the results of this workshop and the results from the UTK workshop, it is believed that there is both viability in the topic and the method. However, given the challenges in this paper recommends a revised workshop series with a targeted approach to upper management buy-in and educator involvement.

Principles of management show that managers must show an interest in the welfare and issues of their employees. In other words, even if the administration is well-trained in Lean Six Sigma and desires to share this with other faculty, the educators are less likely to participate unless self-motivated or required to. This suggestion encompasses both. By improving the meaningful communication between teachers and administration, teachers will feel like their concerns are being heard, and may be more inclined to listen in return. This also lays a foundation for the cooperative work that is essential to problem-solving with Six Sigma. Teachers are already asked to do too much. Programs change yearly, and teachers are required to follow whatever new rules are instituted. Additional programming does not stand a significant chance of success. Taking into account the results from the workshop conducted as part of this study and the teacher feedback received, the following program structures are suggested as potential avenues for further testing and research.

University-Based Workshop Sessions. Another option is a collaboration with the local university. This method may be more feasible due to a reduced requirement for additional funding. In this program, the university would work with the school administrators from several schools in the area to offer workshops on inservice days for educators. Like the workshop conducted in this study, professional development credit would be offered. At the University of

Tennessee at Chattanooga, the courses would likely be taught by the Engineering Management & Technology faculty.

In order to be successful, it is suggested that there be at least one dedicated member from each institution present and active in the discussion while the program is being formulated and instituted. In their study about university/school partnerships, East Carolina University School of Education professors Peel, Peel, and Baker discuss factors that make a difference between a successful collaboration and failure (2002). Key themes mentioned include invested leadership, open collaboration, equal financial investment (or at least an amicable agreement on the financial state), flexibility, and a shared vision (Peel, 2002). The lack of engagement in the workshop this study shows poor performance in each of these categories. As is the case in many program developments, the program was developed entirely by one party and then pitched and forced on the other. Regardless of incentives and promotions, this does not create, as Peel, Peel, and Baker would say, a "'we' mentality" (2002, pp. 324). Workshop sessions should alternate between theory, case studies, and practice sessions. Teachers should have the opportunity to give feedback on what topics they would like to cover.

An extension of this program would include university students in the engineering management program conducting process improvement projects at participating schools. This would give the students valuable experiential learning and demonstrate to educators the benefits of process improvement without expending their resources and time. Risks of this program are similar to those in the pilot workshop: lack of engagement, although this is expected to be mitigated, and lack of adoption.

Process Improvement Coach. Many schools have faculty members who serve as both as educators and coaches for the various sports teams. This idea proposes a similar arrangement for

a process improvement specialist that would devote part of his or her time to running process improvement projects and working with other faculty members and the rest as a part-time faculty member. This reduces the financial burden of a full-time process improvement specialist while creating a good “bottom up” foundation for process improvement. Fields like statistics integrate particularly well with Six Sigma, but having a variety of different fields would lend itself to a better comprehensive perspective.

It is suggested that multiple process improvement coaches be hired at one time in order to support each other and foster an environment for process improvement. Like faculty sports coaches, the process improvement coach(es) would have a reduced course load in order to allow time to focus on their other duties, or receive an additional stipend. Risks of this method include a moderate financial burden and the risk of a lack of support for these coaches, and thus a reduced rate of adoption.

Process Improvement Professional-Led. This strategy focuses on relying on process improvement professionals to lead process improvement and start a movement in schools from both the upper management and grassroots levels simultaneously. Two process improvement professionals would be hired by school district leadership. Experienced Green Belts or Black belts are suggested. These process improvement specialists would be assigned to a school in the district. One process improvement specialist would spend a couple weeks meeting with faculty and administration and getting to know the school. Focus should include areas for a potential improvement and staff who are involved with these areas. One process improvement specialist will lead a six week Lean Six Sigma workshop for administration. Focus will be on cost saving and improvement in other areas. The other specialist will begin a process improvement project. The status of the project should be reviewed during the class sessions, and engagement in the

project encouraged. Teachers with a connection to the project should also be involved. After finishing the workshop, administration will begin a guided improvement project. Workshops would be offered for teachers during this time. After creating a culture of process improvement, these specialists would move to the next school in the district, conducting periodic check-ins with the initial school.

The major risk for this program is funding. Usually, hiring a process improvement professional is justified through saved profits on process improvement projects, but if projects are selected due to teacher buy-in rather than the bottom line, this may be difficult. However, it provides a consistent influence of process improvement, and by addressing both the faculty and administrators, has a better potential for long-term adoption.

Ongoing Developments. A grant was recently submitted by the University of Tennessee Knoxville for a workshop series in collaboration with the University of Tennessee at Chattanooga. The focus is on strengthening the connection between schools and STEM resources at universities. Although not specifically focused on process improvement methodologies or problem solving, this may be an opportunity to integrate process improvement into the curriculum. This would be similar to the University Workshop idea in the recommendations section. Focus would be more on Lean than Six Sigma to make the move towards a more service-oriented program.

Acknowledgements

This research project was supported by a $700 SEARCH Award grant from The University of Tennessee at Chattanooga's Office for Undergraduate Research and Creative Endeavor. Advisors for this project included Dr. Aldo McLean, Dr. Wolday Abrha, and Dr. Seong Dae Kim, all of the University of Tennessee at Chattanooga's Department of Engineering and Technology Management.

Many thanks to my thesis advisor, Dr. Aldo McLean, who collaborated on this project with me. It would not have been possible without you, and I'm very grateful for all the time and effort you put into helping me run the workshop and advising me throughout the entire process. Thank you to Dr. Wolday Abrha and Dr. Seong Dae Kim, who made up my examination committee and provided great feedback over the course of the project. Thanks also to Department Head Dr. Ahad Nasab, for his support; to Bryan Wootan, who designed the flyer and certificate for us; to the four outstanding educators who participated in our first workshop session; to all the educators who spoke with us; to Sara Jackson, who provided us with the contact info for many educators and helped us get the word out; and to Shanae Anderson, who ordered, filed, scheduled, and took care of all the little details to make this happen.

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Appendix A: Workshop Teaching Material

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Problem-Solving Tools & Methods

With tools from Lean and Six Sigma

Madison Chan, CSSYB
Dr. Aldo McLean, PE., CMQ-OE, CSSGB

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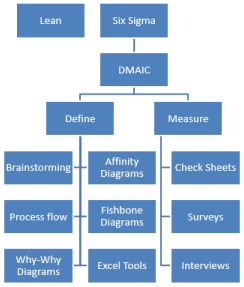
Session Overview



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Let's talk about Brian.

Brian was an assistant principal in Thorton, Colorado.

He was asked to lead the Six Sigma implementation for the school district.

Brian became a Black Belt in Six Sigma, and successfully led a team through the DMAIC process to solve an air quality problem.

Why is this an important case?

Six Sigma was used successfully in schools by a school administrator
Brian had a Black Belt in Six Sigma
For most people, this is too time of a time and monetary investment

Enter this course: a version of what Brian used that has been edited down to core components and is accessible to everyone.

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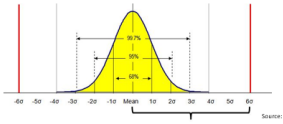
First things first: What is Six Sigma?

- A process improvement methodology, first used and eventually coined by Motorola in 1986
- Goal: reducing variation and defective products to almost nothing
- Literal meaning:
  - All the results/products fall within "six sigmas" or six standard deviations away from the average.
  - 99.999999% of products or results are good, which means only 3.4 defects per million



Source: http://leansixsigmadefinition.com/glossary/six-sigma/

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What is Lean?

- Often used in conjunction with Six Sigma, e.g. "Lean Six Sigma"
  - Both used under the umbrella of continuous improvement
- All about cutting out waste
  - What is waste? Anything that doesn't add value.
- "Do more with less"

Source: https://www.processexcellencenetwork.com/lean-six-sigma-business-performance/columns/8-wastes-of-lean-manufacturing-in-a-services-conte

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So how does this relate to schools?

- Lean and Six Sigma were originally applied to manufacturing
- Other businesses figured out that Lean and Six Sigma can be used to help any process-based system.
- Examples include:
  - Hospital waiting times
  - Consistency in restaurant cooking
  - Customer service expectations
- Schools run on processes too
  - Buses
  - Lunch lines
  - Class times
  - Teaching strategies
  - Student attendance

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Your Team

- Problem solving is a collaborative effort
- Input from all perspectives is important to correctly defining a problem and making sure the solution is the best for everyone involved
- Ideal team size is usually 5-7 individuals
- Make sure you have representatives from each affected area
  - Could be students, faculty, staff, parents, etc.
  - Ask "who uses this process?" and "who has a stake in this process?"

Source: clipart-library.com

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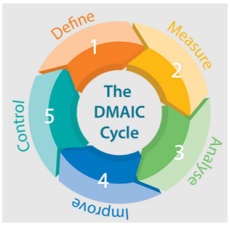
DMAIC

- Foundational Six Sigma tool
- Data driven improvement cycle
- Structured Approach to Problem Solving



Source: medium.com

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Defining

What's the problem we're trying to solve?

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Define

What's the problem that we're trying to solve?

- Goal is to come up with a **problem statement.**
  - What is affected? (defined with numbers)
  - What is the impact?
  - Over what time period?
  - What is the gap?

Source: drivecasa.com

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Examples of Problem Statement

- There are an average of 20 late buses per month, causing the students to be late to class and shortening instruction time.
- This semester, 10% more students than last semester failed the midterm exam.

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Brainstorming

- Technique to quickly generate a large number of ideas
- Good for getting input from many individuals
- Can be **Structured** or **Unstructured**
- Guidelines:
  - No criticism of others' ideas
  - Building off others' ideas is encouraged
  - Quantity over quality

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Brainstorming example: Late Delivery

A pizza place finds out that a number of customers have called and complained about late deliveries. The manager, store employees, and delivery drivers have come together to brainstorm reasons why this might be happening.

- Pizza is made incorrectly and must be remade
- Pizza has to wait before being put into oven
- When toppings run out, employees have to go make more before finishing pizza
- Drivers pick up incorrect order
- Orders have to wait on another component to be ready (like wings)
- Pizzas with more ingredients take longer to make
- Station has to be sanitized if there are dietary restrictions
- Drivers have to stop for gas
- Customer address is hard to find

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Affinity Diagrams

- Grouping by topic
- Organize all the ideas created by Brainstorming
- Enable us to find patterns and areas to focus on
- Look for:
  - Topics that show up in multiple areas
  - One area that has a proportionally more ideas/issues than another

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Example: Pizza Continued

Pizza Making Process

- Pizza is made incorrectly and must be remade
- Pizza has to wait before being put into oven
- When toppings run out, employees have to go make more before finishing pizza
- Pizzas with more ingredients take longer to make
- Station has to be sanitized if there are dietary restrictions

Delivery Process

- Drivers have to stop for gas
- Customer address is hard to find
- Drivers pick up incorrect order
- Orders have to wait on another component to be ready (like wings) before they can be taken

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Process Flowcharts

- Break down a process into steps and decision points
- Good way to reveal problem points that may have been overlooked
- Decision points are "yes" or "no" questions

- Symbols: Why are these important? They make it easier to tell what the chart is trying to explain, especially if the process is a complex one.


Step in the process


Decision Point


Start or End

Direction of Flow

1

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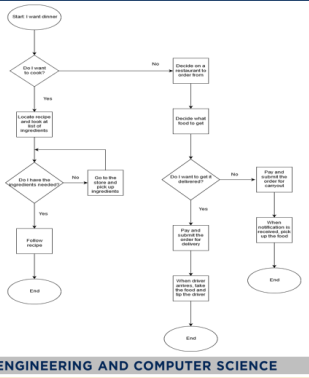
Process Flowchart Example: What do I want for dinner?



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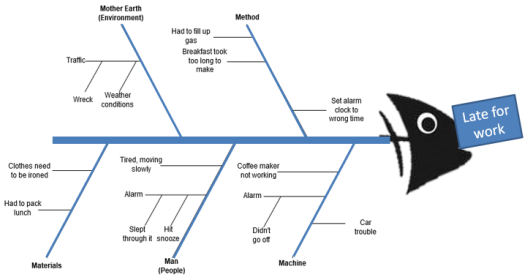
The Fishbone Diagram



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The Fishbone Diagram

- Also called the Ishikawa Diagram or the Cause-and-Effect Diagram
- Starts with an effect (generally the problem) and builds out causes in different categories
- Can be used to define problems more clearly or find the root cause
- Can use the 5 M's if you need inspiration for categories
  - Man
  - Machine
  - Mother Nature (Environment)
  - Methods
  - Materials

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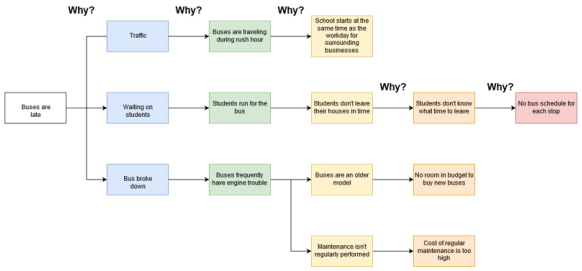
The Why-Why Diagram



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The Why-Why Diagram

- Uses a "chain of symptoms" to find the root cause
- Also called the 5-Why Diagram, because five "Why" statements are often needed to reach the root cause
- Process:
  - Begin with the problem statement
  - Ask why this problem occurs (may have multiple causes)
  - Repeat for each cause
  - Finish when you have reached the 5th why, or when the last why is not answerable

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INTERMISSION

Get snacks. Stretch. Anything we need to change?

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Getting the Data: Check Sheets

- A structured form for discrete data collection
- Tally number of occurrences by category over a set period of time
- Look for patterns or trends
- Good way to monitor a process before, during, and after changes

Telephone Interruptions

Reason	Day					
	Mon	Tues	Wed	Thurs	Fri	Total
Wrong number	𝍸	||	|	𝍸	𝍸 ||	20
Info request	||	||	||	||	||	10
Boss	𝍸	||	𝍸 ||	|	|||	19
Total	12	6	10	8	13	49

Source: asq.org

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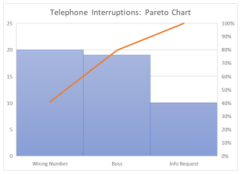
Organizing the Data: Pareto Diagram

- Bar graph organized by decreasing frequency and with a cumulative line
- Created using a check sheet tally
- What categories cause the majority of problems?
- Utilize the **80-20 rule**
  - 80% of problems caused by 20% of products/subjects/etc.



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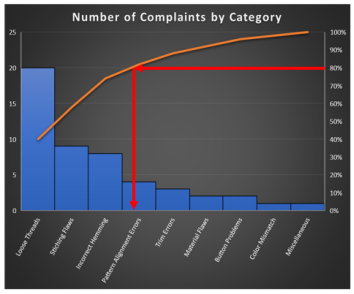
Pareto Diagram Example



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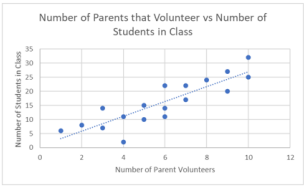
Organizing the Data: Scatter Diagram

- Investigates relationship between two sets of variables
- Visually displays:
  - Strong, weak, or no correlation
  - Correlation can be positive or negative
- Can be used to determine cause and effect



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Collecting and Organizing Data in Excel

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Measuring

Set a baseline and a goal

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Check sheets

- See previous slide
- *Guidelines:*
  - Determine categories for data collection
  - Determine who will be collecting data, the time period the data will be collected over, and the method for collecting it
  - If multiple people are collecting data, verify that everyone is using the same method (provide training or instruction if needed)
- Apps can be an easy way to collect tally
  - Tally Counter for Android
  - Tally: The Anything Counter for IOS

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Online or Paper Surveys

- Use the issue you defined previously to develop relevant questions.
- When to use:
  - Need a big sample size of data
  - Need a quick and inexpensive way to collect data
  - Low response rate is okay
  - Possible answers are known
- Free online options
  - Google Forms
  - Survey Monkey
  - Poll Everywhere (this is a good option for getting students involved and interacting)

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In-Person Interviews

- Sitting down with participant(s) and asking a series of questions.
- When to use:
  - Qualitative data is needed
  - A high response rate is required
  - Interviewee's body language and emotional cues are important
  - Have time to spend
  - Questions are sensitive
  - Answers are not known

Source: making-the-web.com

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End of Instructional Session

Yay!

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Next steps

https://moneyinc.com/10-steps-success-will-always-work/

Part 2: Time to put these skills to the test!

- **Use your new toolkit to define and measure problems you find**
  - Within normal duties
  - Make observations, and try to collect data where it might be relevant
- **We're here to help!**
  - We will check in every two weeks
  - Don't hesitate to reach out if you have questions or want to explore an idea!

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Next Steps continued

Part 3: Kaizen Event in January

- **What is a Kaizen event?**
  - A focused problem-solving session
  - Typically takes place over several days- we'll condense it into a few hours
- **What will this look like?**
  - We'll take one or more of the problems you found and apply the rest of the DMAIC process to find possible solutions
  - End result: a solution that can be tested

After this event, we'll give out certificates.

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Resources

- **ASQ's 7 Quality Tools**
  - https://asq.org/quality-resources/seven-basic-quality-tools
- **Tool for drawing flowcharts and diagrams**
  - https://www.draw.io
- **Contact Info**
  - Madison Chan: gwx288@mocs.utc.edu
  - Aldo McLean: aldo-mclean@utc.edu
  - Or contact us on Slack!


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Want to learn more?
ASQ's explanation of different Six Sigma belts
• https://asq.org/quality-resources/six-sigma/belts-executives-champions
Certified Six Sigma White Belt
• Foundational knowledge, free
• https://www.sixsigmaonline.org/six-sigma-white-belt-certification/
• https://www.sixsigmaonline.org/lean-six-sigma-white-belt-certification/
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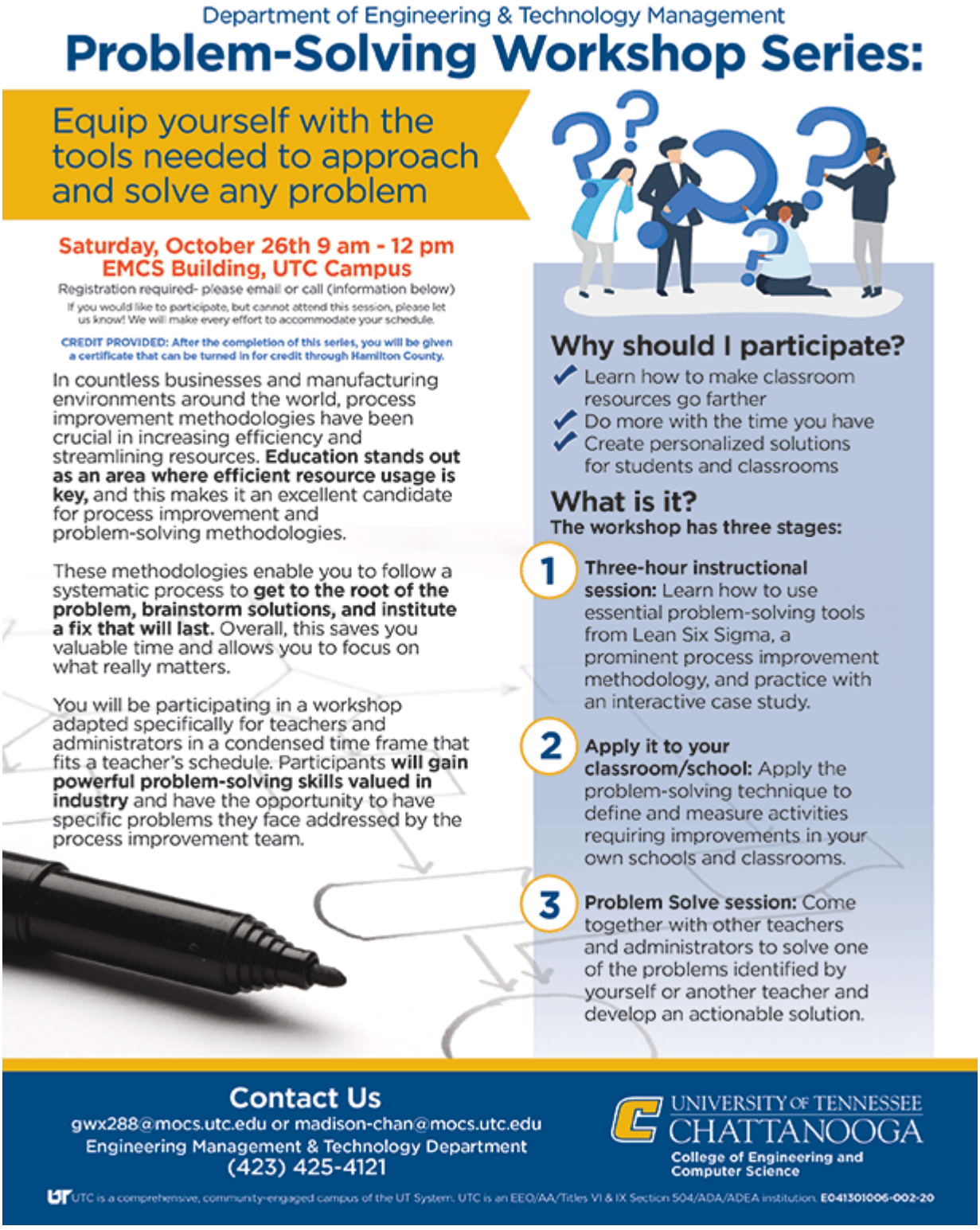
Appendix B: Workshop Promotional Material



Flyer created by Bryan Wootan, UTC College of Engineering and Computer Science Graphic Designer

Appendix C: Workshop Surveys

Milestone Survey

1. **I have used the following tools.**
   Check all that apply.

- [ ] Brainstorming
- [ ] Affinity Diagrams
- [ ] Process Flow Charts
- [ ] Fishbone/Ishikawa/Cause-Effect Diagram
- [ ] DMAIC Process
- [ ] 5-Why/Why-Why Diagram
- [ ] Check Sheet
- [ ] Pareto Chart
- [ ] Scatter Diagram

For the next series of questions, pick a value from 1 to 5 that describes how much you agree with the statement.

2. **I am confident in my ability to use brainstorming as a tool.**
   Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

3. **I am confident in my ability to use affinity diagrams as a tool.**
   Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

4. **I am confident in my ability to use process flowcharts as a tool.**
   Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

5. **I am confident in my ability to use fishbone diagrams as a tool.**
   Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

6. **I am confident in my ability to use the DMAIC process as a tool.**
   Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

7. **I am confident in my ability to use check sheets as a tool.**
   Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

8. **I am confident in my ability to use pareto charts as a tool.**
Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

9. **I am confident in my ability to use scatter diagrams as a tool.**
Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

10. **I am confident in my ability to use why-why diagrams as a tool.**
Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

11. **When confronted with a problem, I feel confident in my ability to address it.**
Mark only one oval.

	1	2	3	4	5	
Not confident	◯	◯	◯	◯	◯	Very confident

12. **There are unaddressed problems in my classroom/school.**
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

13. **I think the tools listed above can be used to solve those problems.**
Mark only one oval.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly agree
- ◯ Don't see any problems

Post-Workshop Survey

Thank you for coming today! We appreciate your time and welcome your feedback to guide future workshops.

1. **To what extent did this workshop meet your expectations?**

2. **Did you find this workshop helpful?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not helpful	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Very helpful

3. **What do you think would have improved this workshop?**

4. **I would recommend this workshop to other teachers and administrators.**
1- Would not recommend, 2- Would most likely not recommend, 3- May or may not recommend, 4- Would recommend with reservations, 5- Would highly recommend
Mark only one oval.

	1	2	3	4	5	
Would not recommend	◯	◯	◯	◯	◯	Would highly recommend

5. **What would you share with someone else from this workshop?**

6. **Additional comments:**

7. **We are considering the following days for the Kaizen Event in January. Please check the boxes for dates you would most likely be able to attend.**
Check all that apply.

- ☐ Friday, January 3rd (Hamilton County Inservice Day)
- ☐ Saturday, January 11th
- ☐ Saturday, January 18th
- ☐ I would prefer a day during the week (if so, specify day of week and time)

Appendix D: Workshop Survey Responses

Milestone Survey

Table 1: Familiarity with Process Improvement Tools

"Have you used the specified tool?"

	Participants, Prior to Workshop				Participants, Post-Workshop			
	#1	#2	#3	#4	#1	#2	#3	#4
Brainstorming	Y	Y	Y	Y	Y	Y	Y	Y
Affinity Diagrams	N	N	N	N	Y	N	N	Y
Process Flow Charts	Y	N	Y	Y	Y	N	Y	Y
Fishbone/Ishikawa/Cause-Effect Diagram	N	N	N	N	Y	N	N	N
DMAIC Process	N	N	N	N	Y	N	N	N
5-Why/Why-Why Diagram	N	N	N	N	Y	N	N	Y
Check Sheet	Y	Y	Y	N	Y	N	Y	N
Pareto Chart	N	N	N	N	Y	N	N	N
Scatter Diagram	Y	Y	N	N	Y	Y	N	Y

Y- Yes N- No

Table 2: Confidence Using Process Improvement Tools

"How confident are you using _____ ?"

	Participants, Prior to Workshop				Participants, Post-Workshop			
	#1	#2	#3	#4	#1	#2	#3	#4
Brainstorming	4	4	5	5	5	5	5	4
Affinity Diagrams	1	1	1	1	4	4	3	4
Process Flow Charts	4	2	3	3	5	4	5	4
Fishbone/Ishikawa/Cause-Effect Diagram	1	1	1	1	5	3	5	4
DMAIC Process	1	1	1	1	5	3	5	3
5-Why/Why-Why Diagram	1	1	1	1	5	5	5	5
Check Sheet	4	5	5	2	5	5	5	3
Pareto Chart	1	1	1	1	4	5	3	3
Scatter Diagram	5	1	1	1	5	4	5	4

1- Not very confident 5- Very confident

Table 3: "When confronted with a problem, I feel confident in my ability to deal with it."

Participants, Prior to Workshop				Partipants, Post-Workshop			
#1	#2	#3	#4	#1	#2	#3	#4
4	4	5	4	5	5	5	4

1- Not very confident 5- Very confident

Table 4: "There are unaddressed problems in my classroom/school."

Participants, Prior to Workshop				Partipants, Post-Workshop			
#1	#2	#3	#4	#1	#2	#3	#4
4	4	5	3	4	5	5	3

1- Strongly Disagree 5- Strongly Agree

Table 5: “I think the tools listed above can be used to solve those problems.”

Participants, Prior to Workshop				Participants, Post-Workshop			
#1	#2	#3	#4	#1	#2	#3	#4
Strongly Agree	Neutral	Strongly Agree	Agree	Strongly agree	Strongly disagree	Strongly agree	Strongly agree

Post-Workshop Survey Results

1. To what extent did this workshop meet your expectations?
    a. It met my expectations
    b. Very informative on how to save "waste", lean to education. Process effectiveness.
    c. This workshop was a great intro to the six sigma/lean concepts and how to possibly apply them in education.
    d. Far exceeded my expectations. This is very beneficial to my work

2. Did you find this workshop helpful? (Scale of 1-10, 1: Not Helpful, 10: Very Helpful)
    a. 7
    b. 10
    c. 10
    d. 10

3. What do you think would have improved this workshop?
    a. Practice using the tools
    b. Structure very well. Those who have only taught academics and had not had industrial experience might need longer time to explore terms and understanding. But A+!
    c. I think the level of instruction today was perfect.
    d. Unsure

4. I would recommend this workshop to other teachers and administrators (1-5, 1: Would Not Recommend, 5: Would Highly Recommend)
    a. 5
    b. 5
    c. 5
    d. 5

5. What would you share with someone else from this workshop?
    a. The tools and where they could be used
    b. That process can save "waste". Time and money is a goal in education in where can we save both? This process addresses the define problem to find a solution.

c. About how the concepts discussed could be used in various facets.
d. Six Sigma Tools

6. Additional comments:
    a. Checking dietary restrictions would be nice (I'm vegetarian); Give wifi access code for guests; funny examples are nice too (humorous flow charts for example)
    b. Admin would benefit from this professional development and would enjoy this thinking "outside the box" avenue.
    c. Thanks for having this workshop!
    d. Very good seminar with tools I can use directly to work on problems.