Session 3247

Developing Practical Skills for Quality Assurance and Metrology Applications in Manufacturing

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Introduction

Sound quality control practices can be critical to the success of a company in the highly competitive global environment. Implementing product changes quickly to meet accelerating customer demands and expectations can challenge both the quality system and the associated personnel. Companies strive to establish a strong quality management team and effective quality procedures, yet many employers find newly hired technical graduates unprepared to apply quality control concepts learned in the classroom. Skills and experiences beyond basic coursework are often necessary for meaningful and correct application of quality control concepts[16]. Most technical manufacturing programs require some level of quality control training including basic coverage of quality management concepts and statistical data analysis, but offer little insight into implementation issues and the practical problems faced by industry[4]. This approach can be quite effective in establishing a basic understanding of quality control theory, but may leave gaps in a student's ability to successfully apply that understanding in the manufacturing environment. Quality control on the plant floor is practiced much differently than it is presented in the classroom with numerous opportunities for inaccurate data collection and unclear conclusions[13]. Experienced quality professionals often find that newly hired graduates have difficulty with issues such as gaging, data interpretation, and conforming to a production and cost oriented environment. While many of these issues are a matter of experience, both industry professionals and the related literature indicate that applied quality concepts should be added to basic quality control curricula at the college level. Every effort should be made to strengthen students' skills by combining theoretical knowledge with practical situations[10]. This paper investigates the practical skills needed by entry level personnel in the quality control environment. The procedure used to gain this information includes:

- In-depth conversations with industry professionals to identify needed skills and specific gaps in entry-level abilities
- Development and validation of a survey tool to determine practical industry requirements of entry-level quality control personnel
- Administering the survey and drawing conclusions from the results

By analyzing the survey results and in-depth conversations with industry professionals, a platform is created for developing and improving quality control curricula.

Practical Requirements in Industry

Successfully applying quality control concepts on the shop floor requires the ability to overcome common problems such as incomplete data, inaccurate measurements, and non-normal distributions. In addition, understanding how the process and product impact the analysis of quality data is critical in making correct judgments[7]. An understanding of basic data collection procedures and protocol and familiarity with quality standards and reference material is also expected. These requirements may seem overwhelming for those in entry level positions, but exposure to a few key concepts before graduation can make the transition much easier. Demanding production schedules and cost constraints can be additional complications for the quality professional to overcome. The key to success is an ability to understand and address these problems without abandoning basic quality theory and standards.

Basic Sampling and Data Collection Standards

Complying with appropriate sampling procedures and documentation practices can be critical to the success of quality evaluations and process monitoring. The sampling method should contain enough data to conduct a complete analysis without the collection of unneeded information that distracts when drawing conclusions[6]. Students often work "textbook" problems without ever considering how to actually design a study or collect data properly. As a result, questions can arise during initial work assignments such as:

- How many parts should be sampled?
- Should parts be identified and saved or returned to production?
- Should samples be drawn consecutively or taken over a period of time?
- What documentation should be generated as a result of the study?

Answers to these types of questions will vary depending on the particular situation, but an introduction to quality standards and procedures can help better prepare students[3]. A familiarity with what guidelines are available and how to find them can be an important first step in addressing these issues. For example, students could be introduced to the sampling procedures for inspection by variables[1]. They could then be assigned a project that requires the determination of appropriate sample size and procedure. Additional assignments might involve appropriate data collection and recording procedures for control charts as described by the American National Standard for Control Charts[2].

Gage Repeatability and Reproducibility

When collecting data for analysis, assuring that accurate gages and gaging methods are used is a critical first step. Incorrect use of common measuring devices such as calipers and micrometers can be a particular problem[9]. Measuring equipment and processes must be well controlled and suited for use in order to assure valid data collection[11]. Students who receive little or no practical experience with measuring devices have difficulty in understanding the seriousness of this issue. Some common pitfalls include:

- Choosing a gage with an inappropriate resolution
- Not understanding that different readings are often obtained when several people use the same instrument to measure the same part
- Not considering that slight differences in measuring techniques such as varying gaging pressure or alignment can result in significant differences in readings
- Using gages that are out of calibration and no longer measure accurately

Many quality control textbooks include a small section addressing basic Gage Repeatability and Reproducibility (Gage R&R) issues along with sample data and problems. Although this can be helpful in introducing the topic, text coverage is usually limited and may receive little emphasis. Given that inaccurate gages and gaging methods are common problems in industry, a strong argument can be made for strengthening gage control coverage at the college level[3]. Hands on projects involving Gage R&R studies and gage control allow students to integrate knowledge with practical situations, strengthening needed skills in the process[10].

The basic Gage R&R study involves a few operators measuring a small number of parts several times each.[5] The study is designed to show how repeatable the measurements are when the gage is used by a number of operators. This type of analysis provides an excellent opportunity for students to practice and reinforce their knowledge. With common gaging devices such as calipers or a micrometer and a few parts to measure, students can conduct a realistic Gage R&R study as a part of the course.

Understanding the Process and Product

Before any quality control study begins a clear understanding should exist of the process and product from which the data is to be drawn. Most quality control training in the classroom includes statistical analysis, control charting, and other basic techniques. Characteristics of particular process and products and how they can influence test results are usually not emphasized. Without making this important link, opportunities for error and misinterpretation are endless. Errors involving incorrect subgrouping of data are particularly common in industry[16]. Students may be quite competent in statistical analysis and quality control procedures yet still make serious errors by not fully understanding the process before analyzing data. Gaining the needed level of insight can be challenging in a basic quality control course. However, considering that every process has its own unique set of circumstances which can impact proper data analysis, the opportunities to demonstrate this link are numerous. The following examples highlight this connection and demonstrate how it can be brought into the classroom.

Consider a drilling process that has a specified diameter of 0.500 inches with an allowable range of 0.498 – 0.503 inches. Most drilling processes have a typical wear characteristic that first causes hole sizes to become smaller over time as the drill wears. As wear continues the hole sizes actually become larger as the tool becomes less stable[12]. Figure 1 shows a typical distribution of hole sizes for such a process. Understanding this process and the associated tool wear pattern can be critical in determining sample size, sample frequency, and the appropriate distribution model to use in analysis. If a capability study for the immediate performance of the process is desired the samples might be taken consecutively or within a short time period.[8] The dashed line in Figure 1 indicates the likely distribution for this scenario. If the process capability for the life of the tool is desired the data must be taken over time as the solid line illustrates. The distribution over the life of the tool is typically skewed and may require additional analysis to properly match it with the appropriate model[14].

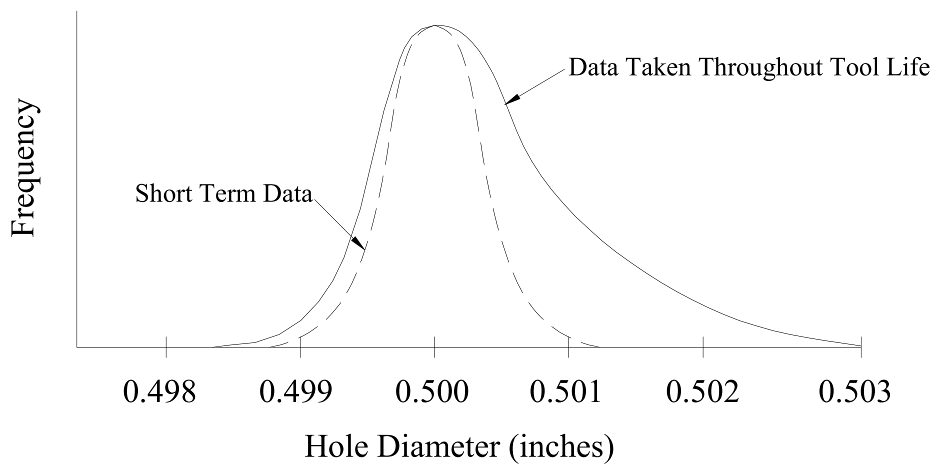

Figure 1. Hole Diameter Distribution

Examples such as this provide excellent opportunities to bring practical experience into the classroom. A possible assignment might be to have students measure hole sizes using a new drill and a worn drill and compare results. Another possible exercise could involve students taking data from a drilling operation over the life of the tool and conducting a capability study. Some insights students can gain by studying a simple drilling process include:

- Many processes are not stable and naturally change over the life of the tool.
- The method of sample selection such as choosing samples consecutively or over time can have a drastic effect on the distribution and thus the capability study.
- Data from manufacturing processes is often non-normal and should be analyzed using the appropriate distribution before proceeding.

The above example demonstrates opportunities for bringing practical situations into the classroom. When students work with specific processes they are better able to understand the link between process knowledge and data analysis.

Survey of Industrial Professionals

In order to gain further insight into the skills needed by entry-level quality control personnel, a survey was developed and pre-tested with colleagues and industry professionals that have significant roles in quality control. Recommendations from the pre-test were considered in the final version of the survey[15]. The survey listed twelve items for the participants to consider in rank-order format. A blank was provided that allowed an additional topic to be written-in during the survey if it was not already listed. Participants were asked to rank the top three quality control items (1,2,3; 1 = highest priority) that they felt most needed additional attention in four-year technical programs.

The survey was distributed to engineers and managers currently working in industry who have a significant role in quality control. A total of 28 questionnaires out of 40 were returned for a return rate of 70 percent. The survey was evaluated by applying a number score to the ranked responses. Highest priority items were assigned a score of 3 followed by 2 and 1 for lower priority rankings. The scores for all survey items were then tabulated and reported. Table 1 shows a complete listing of the responses and the associated scores. Figure 2 shows a pareto chart of the results by score for the top ten items.

Rank	Topic	Score
1	Capability Analysis	28
2	Statistical Process Control	25
3	Basic Statistics	19
4	Design of Experiments	15
5	Economic Aspects of Quality	12
6	Gage Control	11
7	Hypothesis testing	9
8	Sampling	8
9	Measuring Equipment	7
9	Data collection Standards	7
11	FMEA	3
11	Juran Concepts	3
13	Non-Normal Distributions	2
14	Rational Subgrouping	1

Table 1. Complete Listing of Responses by Score

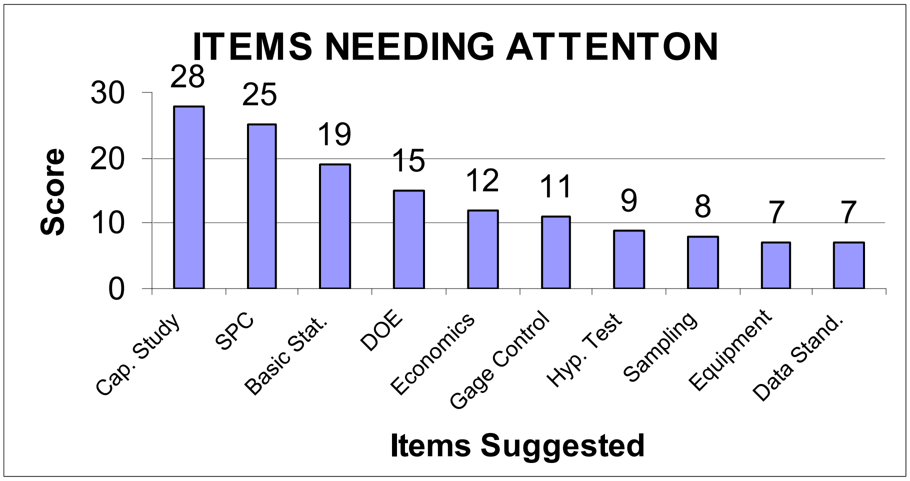

Figure 2. Pareto Chart of Top 10 Topics Suggested

Summary of Findings

The purpose of this paper was to identify practical skills needing additional attention in preparing graduates for entry-level positions involving quality control. The survey indicated several specific applications of statistical theory that should be given more attention in the classroom. Capability studies and statistical process control are at the top of the list for further emphasis. Additional items such as design of experiments, economic aspects of quality, and gage control were also prominently mentioned. A basic understanding of statistics was also listed as a concern. Design of experiments and the economic aspects of quality are more specialized areas that may require additional courses that focus on these topics. It is somewhat surprising that prominent topics such as capability studies, statistical process control, and gage control are listed as concerns. Most texts and quality control courses include these items as major topics. One reason for this perceived deficiency may be the level of exposure students receive in these areas. Based on the more in-depth personal interviews with industry professionals, students often have some understanding of the basic theory but little practical knowledge of the overall process or of problems typical of these studies. This may be explained in part by the typical textbook coverage of these topics. Problems and exercises often involve a given data set that is used to demonstrate various applications such as the calculation of control limits or C_{pk} values. In many cases students are not exposed to critical ancillary issues such as determining the timing and size of sampling plans, dealing with inaccurate data collection, using basic measuring equipment, and relating the results of the study to specific characteristics of the process.

An understanding of basic statistics is also listed as a concern. This may indicate a problem with prerequisite mathematics courses that provide a foundation for the study of quality control. It may also indicate that quality control curricula should further emphasize statistical theory that supports common quality applications.

Suggested Classroom Activities

Developing meaningful classroom activities is critical in implementing curricular revision into a basic quality control course. The following practical exercises are offered as possible options.

Capability Analysis: Obtain 30 production parts such as small fittings, castings, or stampings along with a corresponding drawing from a local manufacturer. The samples should all be identical part numbers or models and be drawn from the same batch or lot. Require students to measure and record the dimension of a feature or features from the parts with calipers or some other hand held measuring instrument. Using the data and the specifications on the drawing have students calculate the C_p and C_{pk} for the parts and interpret the results.

Statistical Process Control: Collect parts from an ongoing process. This could be from the school's machining lab or from a local manufacturer that has agreed to cooperate in the project. Collect samples at consistent time intervals from the process and preserve the order of collection. Have students calculate control limits and plot the data on control charts. Ask students to relate any indications of assignable cause to performance parameters of the process.

Gage Repeatability and Reproducibility (Gage R&R): Using the same parts as with the capability study conduct a gage R&R study. Select a dimension and five parts that can be measured with a simple hand held instrument. Select two students to measure and record data from each of the five parts three separate times in random order. Using the average and range technique[5] generate two separate Gage R&R studies using two different measuring instruments (for example: calipers and a dial indicator). Compare the performance and suitability of the two measuring instruments.

Process Analysis: Using a simple twist drill, machine holes in metal samples. Preserving the order of data collection, save drilled hole samples throughout the life of the drill. Using calipers, have students measure and record the hole diameters. Plot hole diameter versus drill service time and identify trends in the hole size. Using a suitable machining reference[12] have students speculate on the effect of drill condition on hole size.

Recommendations

Based on both the industry survey and in-depth conversations with industry professionals several areas of concern relating to quality control education were identified. The following recommendations are made considering this input:

- Provide additional coverage of the most common applications in quality such as capability studies, statistical process control, and gage control. These areas should be practiced enough to become second nature so that students are ready to apply them as they begin their careers.
- Supplement problem solving with hands on exercises that encompass the entire process. If a laboratory section is not included in the course, bring sample parts to

class along with calipers and micrometers. Require students to experience data collection, analysis, and interpretation all in one process to gain a better overall grasp of the method.

- Include discussions of specific process characteristics and how they influence the interpretation of data. An understanding of specific tool wear patterns, one-sided specifications, multiple part sources such as mold cavities, etc. can help instill the importance of process knowledge in data interpretation .
- Provide additional emphasis on statistical theory that directly relates to key quality control methods. Taking extra time to clearly define concepts such as standard deviation, the normal distribution, and the related probability characteristics can be critical in understanding capability studies, statistical process control, and gage repeatability and reproducibility.

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