

Institute for  
Improvement in  
Quality and  
Productivity



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## Effective Problem Solving

G. Dennis Beecroft

*Dennis is the Managing Director of the IIQP. He has extensive work experience both in industry and at the University of Waterloo. He works with many companies on their quality issues.*



G. Dennis Beecroft

Most people in the work place are continuously faced with problems to be solved, sometimes daily. Often when problems have been resolved they tend to reoccur at some later time. Effective problem solving, finding the real reason that the problem occurred and then eliminating this reason, or root cause, requires a very disciplined approach. Unfortunately many times a "quick fix" is used. This approach often focuses on a symptom of the problem rather than the root cause therefore the solution selected will not eliminate the problem and it reoccurs.

There are many quality improvement problem-solving models: Xerox 6-step, Proctor & Gamble 8-step, GM 5-phase, Ford 8-D, and Chrysler 7-step. They are all good models and tend to follow the same basic steps. It is important for an organization to adopt a problem-solving model and then keep strictly to the discipline of using it.

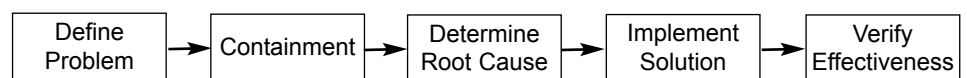
A typical 5-step model might include the following:

1. Define Problem
2. Containment
3. Determine Root Cause
4. Implement Solution
5. Verify Effectiveness

### Define Problem

One of the most important steps in problem solving is to clearly define the problem. The problem also needs to be quantified and a goal established for solution. Helpful questions might be - how big is it? Where and when does it

### Problem Solving Model



## Effective Problem Solving

... Continued from Page 1

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### **Letters to the Editor**

We welcome your comments.

The editor reserves the right to edit all submissions.

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Please Circulate and Recycle

happen? How do you measure it? How will you know if it is gone? This step often requires data collection over a period of time.

It is important to recognize that all work is a process and to solve any problem the current process or method being used must be changed. Too often the solution selected to solve a problem is to "retrain". This will not solve a problem. If the initial training allowed the problem to occur, retraining is not the solution. Process mapping or flow-charting is an excellent tool to assist in understanding the current method or process being used.

#### **Containment**

When problems occur it is best to isolate the suspect product from the system to prevent further processing. This nonconforming product must be either corrected or scrapped. However, in many cases production has not been stopped until the problem is resolved. Special action must be taken to ensure that if other nonconformances are being produced that they are also detected during this period until the root cause of the nonconformances has been eliminated.

#### **Determine Root Cause**

This is a critical and key step in the problem solving process. Further data collection may be necessary to isolate the root cause. Brainstorming tools, such as Cause & Effect Diagram or Affinity Diagram, are also very useful in trying to determine the possible root cause of a problem. Once possible root causes are generated, the most likely are selected and then tested for validity. Sometimes it is useful, as an alternative to selecting the most likely, to eliminate the obviously incorrect possible root causes. Tree diagrams are very useful aids in root cause analysis.

#### **Implement Solution**

Once the root cause of a problem has been determined the next step is to generate a solution to eliminate this

root cause. Too often the solution selected by an organization is to add an inspection step to catch the problem should it reoccur. This is a non-valued solution as the problem is still there. A better approach is to eliminate the root cause and prevent any reoccurrence of the problem. Sometimes it is necessary to generate more than one solution and then select the one that is the most cost effective. Implementation of the solution may result in new procedures being developed and implemented with appropriate new training for the individuals involved. An implementation plan also needs to be developed to ensure that the change is put in place effectively.

#### **Verify Effectiveness**

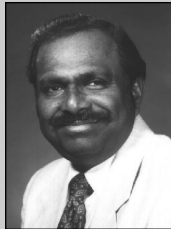
This last step often is omitted. However, problems reoccur unless the root cause is eliminated. Therefore, it is necessary to ensure that the solution implemented did eliminate the root cause. Sometimes it is possible to turn the solution on and off. Where this is not possible an effective measurement method is required.

Effective problem solving is time consuming. Not having time to devote to this approach is one of the main rationalizations given by organizations for not completing all the steps in the problem-solving model. It would appear that in many organizations there is *never time* to eliminate "root causes of problems"; however there is *always time* to "correct nonconformances". Unless time is taken to eliminate the root cause of the nonconformances, the time concern will continue to escalate as more and more problems occur consuming more and more time. ♦

# Measuring Process Capability

Bovas Abraham

Bovas is the Director of the IIQP and has been a consultant with the Institute since its inception. His main areas of interest include Quality Improvement, and the management and implementation of statistical procedures.



Bovas Abraham

As part of their quality improvement programs, many organizations keep track of some 'capability' measures intended to indicate how well their processes are performing. Often these are unitless quantities which compare the variation in the process with process specifications.

Several capability indices are around and we will consider two of them here. We use the notions  $I_p$  and  $I_{pk}$  instead of

that actual process spread ( $6\sigma$ ) and allowed process spread (USL-LSL) are the same implying that 99.73% of the parts are within specifications. If this is the case, then the process is said to be "just capable". It is desirable to have  $I_p$  values greater than one so that the process is capable provided that it is on target. If the process is not on target then  $I_p$  can be misleading.  $I_{pk}$  on the other hand is intended to take into account the fact that the process may not be on target. The larger the value of these indices, the better the performance of the process.

### Estimation of the Indices

The indices defined earlier contain some unknown quantities,  $\sigma$  = process standard deviation and  $\mu$  = process mean and these are to be estimated from data. Hence, questions such as (i) how to collect data, (ii) how long a timeframe should be used, etc. need to be considered.

the average range of the subgroups and  $d_2$  is a constant which depends on the subgroup size. The resulting index is called  $C_p$  and hence

$$C_p = (USL - LSL) / (6\bar{R} / d_2)$$

Alternatively from all the subgroups together the sample standard deviation (S) can be used to estimate  $\sigma$ . The corresponding index is

$$P_p = (USL - LSL) / (6S)$$

### $I_{pk}$ Index

For this index we need an estimate of the process mean,  $\mu$ . This is taken as  $\bar{X}$ , which is the average of all subgroup averages. As before,  $\sigma$  can be estimated using  $\bar{R} / d_2$  or S.

The corresponding indices are:

$$C_{pk} = \text{Smaller of } \left( \frac{USL - \bar{X}}{3(\bar{R} / d_2)}, \frac{\bar{X} - LSL}{3(\bar{R} / d_2)} \right)$$

$$P_{pk} = \text{Smaller of } \left( \frac{USL - \bar{X}}{3S}, \frac{\bar{X} - LSL}{3S} \right)$$

### Comparison of $C_{pk}$ and $P_{pk}$

The numerators of both  $C_{pk}$  and  $P_{pk}$  are the same. Thus, the difference between  $C_{pk}$  and  $P_{pk}$  is in the way  $\sigma$  is estimated from data. As given earlier,  $C_{pk}$  uses the within subgroup variability,  $\bar{R} / d_2$ , while  $P_{pk}$  uses S which is a measure of the total variation in the process during the reporting time period under consideration. Hence, S includes the within subgroup variation and the between subgroup variation. If the process is stable, then the between subgroup variation is small and S and  $\bar{R} / d_2$  are close. Thus, a large difference between  $C_{pk}$  and  $P_{pk}$  is indicative of process instability. Typically  $P_{pk}$  is smaller than  $C_{pk}$  for the same data. Comparison of  $C_p$  and  $P_p$  is similar to that between  $C_{pk}$  and  $P_{pk}$ .

$$(i) \quad I_p = \frac{\text{Allowed process spread}}{\text{Actual process spread}} = (USL - LSL) / 6\sigma$$

where

USL = Upper specification limit

LSL = Lower specification limit

$\sigma$  = Process standard deviation (a measure of actual process spread).

Sometimes this is referred to as  $C_p$  in the SPC literature.

$$(ii) \quad I_{pk} = \text{Smaller of } \left( \frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma} \right)$$

where  $\mu$  = process mean. This is sometimes referred to as  $C_{pk}$ .

$C_p$  and  $C_{pk}$  to avoid confusion. This will become clearer later on.

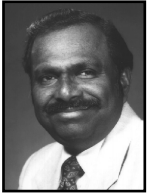
These definitions are motivated by the fact that the process is bell shaped, (Normal distribution) which implies that  $6\sigma$  is the actual process spread covering 99.73% of the parts. Thus, if the process is on target ( $\mu$  = process mean = target), then  $I_p = 1$  indicates

### $I_p$ Index

The denominator of this index contains  $\sigma$ , a measure of process variation. The smaller the variability the larger the index and better the capability. Usually  $\sigma$  is estimated in two different ways. Typically data are collected in subgroups of 4 or 5 consecutive parts over a specified time. Then a measure of within subgroup variation ( $\bar{R} / d_2$ ) is used to estimate  $\sigma$  where  $\bar{R}$  represents

# Upcoming Courses

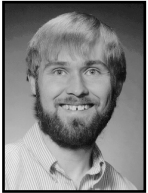
## Meet some of our Course Instructors ....



**Bovas Abraham**  
*Director, IIQP*



**G. Dennis Beecroft**  
*Managing Director, IIQP*



**Hugh Chipman**  
*Consultant, IIQP*



**Jock MacKay**  
*Consultant, IIQP*



**Stefan Steiner**  
*Consultant, IIQP*



**Gary Waller**  
*Associate Provost, Academic and Student Affairs, UW*

## Cost of Quality for Continuous Improvement

TWO DAY COURSE

### Course Description

Cost of Quality (COQ) is an excellent continuous improvement (CI) management tool. COQ can be used effectively to identify, prioritize and then track CI projects by breaking down quality costs into four standard categories: prevention, appraisal, internal failure and external failure.

### You Will Learn

- ◆ To Categorize Elements of COQ
- ◆ Select and Track Projects
- ◆ Choose Vendors and Price Products Using COQ
- ◆ Use Cost of Quality for CI in QS-9000 and ISO 9000

### Who Should Attend

- ◆ Financial Officers
- ◆ Quality Managers and Professionals
- ◆ Continuous Improvement Team Leaders

### Course Dates

October 16-17, 2001  
February 7-8, 2002

### Cost

\$695 (+GST)

*Cost Includes: tuition, course notes, handouts, lunches, coffee and refreshments.*

NEW

# Advanced Data Mining

ONE DAY COURSE

## Course Description

More and more companies have enormous databases which may contain undiscovered but useful information. Data mining is the search for this information using statistical models and computational techniques. This one day course will illustrate the state of the art, using real data from direct marketing, drug discovery and industrial control problems.

## You Will Learn

- ♦ What is Data Mining?
- ♦ Methods for Preprocessing Data
- ♦ Graphical Exploration of Data
- ♦ Classification and Regression Techniques
- ♦ Clustering

## Applications in the Course Include

- ♦ Direct Marketing
- ♦ Drug Discovery
- ♦ Process Monitoring with High Dimensional, High-Volume Data

## Course Dates

October 23, 2001  
January 31, 2002

## Cost

\$350 (+GST)

*Cost Includes: tuition, course notes, handouts, lunch, coffee and refreshments.*

# Design of Experiments

TWO DAY COURSE

## Course Description

A designed experiment is a special type of process study that involves changing one or more process characteristics to investigate their effects.

Design of Experiments (DOE) is one of the continuous improvement tools in Six Sigma and ISO 9001:2000. This two day course will teach you how to effectively use this key methodology to improve quality and reduce costs.

This course will provide you with the right tools to understand, plan and execute an experiment. You will also gain the experience in deciding if experimentation is a good approach to your particular problem(s).

## You Will Learn

- ♦ What is an Experiment?
- ♦ Experiments vs. Other Data Based Approaches
- ♦ Complete Factorial Experiments - looking at several factors simultaneously
- ♦ Fractional Factorial Designs - efficient ways to look at many factors
- ♦ Taguchi's Robust Designs to Reduce Variation
- ♦ Implementation - Planning and Executing Experiments

## Course Dates

November 8-9, 2001  
March 7-8, 2002

## Cost

\$695 (+GST)

*Cost Includes: tuition, course notes, handouts, lunches, coffee and refreshments.*

NEW

# Effective Problem Solving

TWO DAY COURSE

## Course Description

Effective problem solving involves a disciplined methodology and the use of appropriate tools. This workshop teaches a 5-step problem solving model - define problem, containment, determine root cause, implement solution and verification of solution, and tools to be used at the various steps within the problem solving process.

## You Will Learn

- ◆ How to Correctly Define the Problem
- ◆ Understand Work as a Process
- ◆ Identify Different Types of Problems
- ◆ Define Processes Using Process Maps
- ◆ Learn the 5-Step Problem Solving Model
- ◆ Practice the Use of Problem Solving Tools

## Who Should Attend

- ◆ Quality Managers and Professionals
- ◆ Quality Improvement Team Members

## Course Dates

October 29-30, 2001  
February 14-15, 2002

## Cost

\$695 (+GST)

*Cost Includes: tuition, course notes, handouts, lunches, coffee and refreshments.*

# Training Effectiveness

ONE DAY COURSE

## Course Description

Training effectiveness is a requirement for ISO 9001 Quality System Requirements under Element Training. This introductory workshop is based on the Kirkpatrick Model.

## You Will Learn

- ◆ Options and Recommendations for Developing Evaluations
- ◆ Procedures for Measuring Effectiveness
- ◆ Roadblocks to Effective Evaluation
- ◆ How to Evaluate at the Four Levels (Reaction, Learning, Behaviour and Results) and Pros and Cons of Different Approaches

## Who Should Attend

- ◆ Human Resources Personnel
- ◆ Training Professionals
- ◆ Management Leaders
- ◆ Quality Professionals

## Course Dates

November 6, 2001  
March 21, 2002

## Cost

\$350 (+GST)

*Cost Includes: tuition, course notes, handouts, lunch, coffee and refreshments.*

NEW

# Understanding Six Sigma

## ONE DAY COURSE

### Course Description

Six sigma is an improvement system which is seen as a business strategy to gain the knowledge needed to obtain better quality products and services faster and cheaper. More and more companies are trying to implement this system. This one day course is mainly oriented to people from small to medium companies who are contemplating about undertaking a six sigma initiative. This course will provide an overview of the six sigma system.

### You Will Learn

- ♦ What is Six Sigma?
- ♦ DMAIC Process
- ♦ Statistical Thinking
- ♦ Variation Reduction
- ♦ Six Sigma and Process Capability
- ♦ Statistical Tools in Six Sigma
- ♦ Training in Six Sigma

### Course Dates

November 22, 2001  
April 5, 2002

### Cost

\$350 (+GST)

*Cost Includes: tuition, course notes, handouts, lunch, coffee and refreshments.*

# Statistical Process Control

## ONLINE COURSE

### Course Description

This new course is equivalent to a 2 day (14 hours) short course on Statistical Process Control (SPC). This online course is developed for people involved in process control and improvement activities. It will provide an understanding of the basic concepts of Variation, Stability, Capability, etc.

### Course Contents

- ♦ Understanding Variation
- ♦ Charts for X-Bar and R
- ♦ Charts for Individuals
- ♦ Sampling for Charts
- ♦ Process Capability
- ♦ Charts for Attribute Data

### For More Details Visit:

[www.iiqp.uwaterloo.ca/SPC/main.htm](http://www.iiqp.uwaterloo.ca/SPC/main.htm)

### Registration Information

Use the online form to register. Once the form and payment is received a user name and password is issued via e-mail.

### Course Available Online

September 1 to December 20, 2001  
January 2 to April 30, 2002

### Cost

\$195 (+GST)

NEW

# The Best of Statistical Engineering

TWO DAY COURSE

## Course Description

Statistical engineering is a combination of statistical strategies and tools carefully selected to efficiently solve chronic problems in high volume manufacturing. Statistical engineering attempts to exploit observational data from your existing process to “home in” on the root cause of problems.

This two day course covers the guiding strategies and tools you need to effectively apply this exciting methodology to improve quality and reduce costs. This course is a requirement for our new Statistical Engineering certification program, and is also a good compliment to the Design of Experiments two day course.

## You Will Learn

- ◆ Guiding Principles of Statistical Engineering
- ◆ Structured Problem Solving Strategy - diagnostic and remedial journeys
- ◆ Progressive Search and Families of Variation
- ◆ Clue Generation Methods - using observational data to efficiently guide improvement efforts

## Course Date

November 1-2, 2001

## Cost

\$695 (+GST)

*Cost Includes: tuition, course notes, handouts, lunches, coffee and refreshments.*

# Third Edition ISO 9001:2000 An Updating Overview

ONE DAY COURSE

## Course Description

This course is designed for organizations who are already registered to ISO 9000 and need to know more information on the updated edition.

The Third Edition ISO 9001:2000 has made several changes creating a more user friendly standard. It has simplified its language, reduced the required documentation, and made several changes based on customer and user feedback. This edition will be easier to implement, use and upgrade from the previous editions.

In this updating course, find out about the changes and how it impacts your organization and your registration status.

## You Will Learn

- ◆ Background on 2000 Edition
- ◆ Overview of Changes
- ◆ Impact on Current Quality System
- ◆ Transition Guidance
- ◆ Review of Critical Changes
- ◆ How to Implement Changes
- ◆ Changes to Auditing

## Course Dates

September 18, 2001

November 13, 2001

March 14, 2002

## Cost

\$350 (+GST)

*Cost Includes: tuition, course notes, handouts, lunch, coffee and refreshments.*



# Statistical Process Control

## TWO DAY COURSE

### Course Description

Statistical Process Control deals with data based decisions about actions affecting a process. This two day course is developed for people working in industry who are involved in process control and improvement activities. This course will provide an understanding of the basic concepts of Variation, Stability, Charting and Process Capability.

### Course Contents

- ◆ Understanding Variation
- ◆ Charts for X Bar and R
- ◆ Charts for Individuals
- ◆ Sampling for Charts
- ◆ Process Capability
- ◆ Charts for Attribute Data

### Course Dates

November 29-30, 2001

April 25-26, 2002

### Cost

\$695 (+GST)

*Cost Includes: tuition, course notes, handouts, lunches, coffee and refreshments.*

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## REGISTRATION INFO

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**University of Waterloo**  
**Waterloo, Ontario N2L 3G1**

**Tel:** (519) 888-4593

**Fax:** (519) 746-5524

**E-Mail:** [iiqp@math.uwaterloo.ca](mailto:iiqp@math.uwaterloo.ca)

### More Information

- ◆ All IIQP courses can be tailored to suit specific needs or applications and presented within your company. Such courses are often developed by modifying or combining existing courses, depending on the request.
- ◆ Instructors are University of Waterloo faculty and IIQP staff who are professionals with extensive industrial training and consulting experience.
- ◆ Please add GST to all course fees (GST#: R119 2606 85)

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## Measuring Process Capability

... Continued from Page 3

### Variability in the Indices

Suppose we estimate capability from a sample of 50 parts; if it is calculated again from the next 50 parts (with no change in the process) the capability value need not be the same as before. It is important to keep such variability (sampling variability) as small as possible. It is also important to have a realistic estimate of  $\sigma$ . In this context, the following issues are to be considered.

- (i) The number of measurements needed to calculate the capability index.
- (ii) An appropriate sampling plan.

Regardless of the capability index if it is based on insufficient data the variability could be higher. If only 30 parts are used to obtain an index, the sampling error could be as high as 25%. This means that if we take a second sample of 30 parts, the  $C_p$  value obtained could be 25% higher or lower even though the process did not change. If the number of parts is 100 the sampling error is about 15% and hence it is a good idea to have a  $C_p$  and  $C_{pk}$  value based on at least 100 parts.

The variability in the capability index also depends on the sources represented in the sample. This implies that the sampling plan used to generate the index is crucial. If the different sources contributing to the variation in the process are not represented in the sampling plan, the capability index does not give an accurate prediction of the process capability and it can be misleading. For instance, if a  $C_{pk}$  is generated from 100 parts sampled from the last day of the month, it may not give an accurate picture of the process for that month, unless the process is stable from one day to the next which implies that the last day is like any other day. Otherwise, it is simply an indicator of how the

process is doing for the last day of the month. The sources of variability during the month have to be allowed into the sample for the index to have some meaning. A true capability index should include all the sources of variability relevant for the purpose.

The capability also depends on the timeframe (or period of sampling). For example, in certain contexts the requirement may be to select parts from a run of 200 pieces. For many processes this takes a very brief time. Data collected over such a short period may not reflect how the process will behave over a much longer period, say 25,000 pieces. If samples are selected over a short time period, the capability is short term and may not reflect longer term performance.

### Distribution

As mentioned earlier, the capability indices are motivated by the normal distribution (bell shaped curve). There are many situations, however, where such a distribution is inappropriate; dimensional measurements such as out of round, surface roughness, cannot be less than zero. Some other distribution curves would be better in such cases. Capability indices such as  $C_{pk}$  and  $P_{pk}$ , etc. in these cases can be misleading and users must be aware of this.

Summarizing a process with one number is not an easy task and may not be a good idea sometimes, but it is very tempting since it is very simple. Hence, it is crucial to be aware of the issues surrounding the calculation of a one number summary of the process.♦

## SPC Online

This is a new online course developed for people working in industry who are involved in process control and improvement activities. The material covered in this course is equivalent to what is covered in a two day (14 hours) SPC course. Although it will show some calculations, the course will focus mainly on ideas and concepts in Statistical Process Control. Those who complete the course will have an understanding of the basic concepts of Variation, Stability, Charting, and Process Capability.

In order to complete the course requirements, students have to pass a final test given at the end of the course material.

A 'Certificate of Accomplishment' will be issued to those who complete the course successfully. This will enable you to receive 2 continuing education units from the American Society of Quality (ASQ).

### Course Contents

- Chapter 1: Introduction to SPC
- Chapter 2: Control Charts for X Bar and R
- Chapter 3: Sampling for Control Charts
- Chapter 4: Process Capability
- Chapter 5: Control Charts for Attribute Data
- Final Test

**For Course Contents  
and  
Registration Details Visit:**

<http://www.iiqp.uwaterloo.ca/SPC/main.htm>

## 2001 IIQP Research Reports

RR-01-01

### Interpretable Dimension Reduction

H.A. Chipman and H. Gu

RR-01-02

### Differencing a Time Series and Modifications to the Variogram

B. Abraham and N. Balakrishna

RR-01-03

### Multivariate Prediction with Latent Variables

B. Abraham and G. Merola

RR-01-04

### Time Series in Industry and Business

B. Abraham and N. Balakrishna

RR-01-05

### Dimension Reduction Methods Used in Industry

G. Merola and B. Abraham

RR-01-06

### Uniform Coverage Designs for Molecule Selection

R.L.H. Lam, W.J. Welch and S.S. Young

RR-01-07

### Scale Counting

S.H. Steiner and R.J. MacKay

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# electronic

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Visit

[www.iiqp.uwaterloo.ca/newsletter.html](http://www.iiqp.uwaterloo.ca/newsletter.html)

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Their continued support throughout the year has been invaluable.  
Their support contributes to the success of this newsletter. Thank you!

## **An IIQP Networking Seminar Invitation ...**

Thursday, October 25, 2001  
Davis Center, Room 1302  
University of Waterloo  
8:30AM - 11:45AM  
Cost: \$100

Six Sigma defines both a very high quality level (3.4 defects per million opportunities) and a comprehensive methodology for achieving such quality levels throughout an organization. The seminar topics include:

- ◆ Definition of Six Sigma quality in terms of process standard deviation, process centering and specification limits
- ◆ Proper identification of defect opportunities
- ◆ Impact of process drift on quality levels - assuring robustness
- ◆ How Six Sigma in component parts or processes impacts overall quality
- ◆ Definition and application of DMAIC methodology
- ◆ Critical success factors for Six Sigma
- ◆ Examples in engineering, manufacturing and services areas

understanding

# SIX sigma

*Presenter Dr. John Schottmiller*

Dr. John Schottmiller is a certified Six Sigma instructor who has provided training and consulting in Six Sigma for such world class practitioners as Motorola, Eastman Kodak and GE Capital. John has successfully led Six Sigma efforts in engineering, manufacturing and service areas.

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To Register: Contact the IIQP by faxing this page back to (519) 746-5524 or by calling (519) 888-4593.  
Enrolment Limited to 100 Registrants

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### **IIQP NEWSLETTER**

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