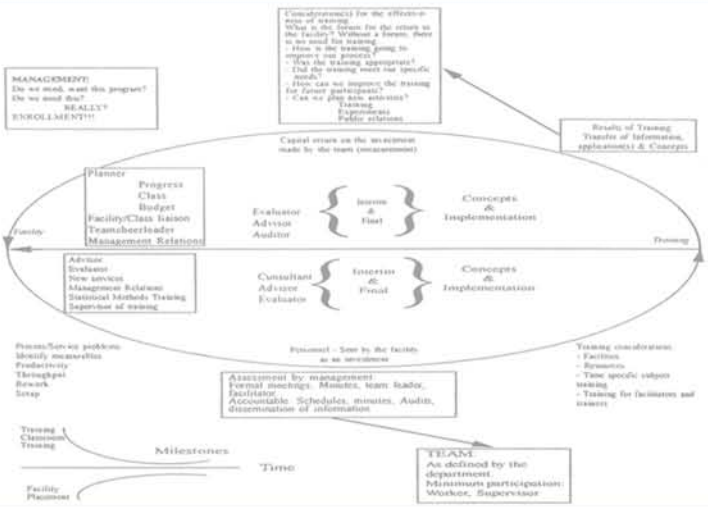
D. H. Stamatis

SIX SIGMA AND BEYOND

The Implementation Process



St. Lucie Press

SIX SIGMA AND BEYOND

The Implementation Process

SIX SIGMA AND BEYOND

A series by D.H. Stamatis

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Foundations of Excellent Performance

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Volume VII
The Implementation Process

D. H. Stamatis

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To

John and Helen Chalapis
(my teachers, mentors, friends and Koumbari)

Preface

In the first six volumes of this series, we followed a traditional writing style to explain, modify, and elaborate points, concepts, and issues as they pertained to the Six Sigma methodology. This volume is quite different and may be considered somewhat unorthodox. There are at least two reasons for this drastic shift in writing style. The first is that the material has already been presented in a very detailed fashion in the individual volumes; therefore, there is no need to repeat them. Second, this volume is an implementation volume, which means that the information is geared toward helping the reader in formalizing his own training, whatever that may be.

We are very cognizant of the fact that a variety of organizations exist, each seeking its own application of the Six Sigma methodology. That is why we have developed the material in such a way as to help the reader in the development of his own needs.

The predominant break of the material is Part I, in which we provide material essential to the reader in developing his own training. All human learning is about skills, knowledge, and attitudes (SKAs). Since we believe that these three attributes are the drivers for learning we have spent several chapters making sure that SKAs are identified and planned in the training. We believe that with the basic tools described in these chapters anyone can create a system for training adults that is much faster, has high user validity, and is exceptionally adaptable. (This is very important because part of the implementation process requires that black belts cascade the training to green belts.)

The second break is Part II, in which we give the reader a prescriptive approach to training. We start by identifying the executives, champions, master black belts, black belts, and green belts and providing a general overview of the Six Sigma methodology. Within each of the groupings we also identify the objectives that each category should be responsible for and then gradually present the training outline for three options: 1) transactional, 2) technical, and 3) manufacturing. The outline is somewhat thematic in nature and in some places repeats what is contained in earlier chapters due to overlap in the knowledge requirements of the various levels of leadership. The reader is encouraged to return to the main volumes to extract more material and examples. (Although we would encourage the reader to generate personalized examples from his own processes.) In some cases, the outline merely identifies a topic without further explanation, for example, FMEA, TRIZ, QFD, control charts, capability, capability indices, DOE, Taguchi, and others. The reason for such laconic statements is that we have gone to great lengths to explain these terms elsewhere in earlier volumes. On the other hand, there are situations in which we find it necessary to either elaborate or explain or reemphasize certain issues, even though we have already explained them. This is because these items are very important in the process of Six Sigma.

The third significant break is Part III, in which we discuss the training for DFSS and certification. This part also contains an epilog. The approach is the same as that described above.

In addition, the reader will notice that the objectives are identified in such a way that transactional, technical, and manufacturing executives, champions, master black belts, black belts and green belts may benefit from the information. They are all grouped together in their respective categories. (For example, the objectives for the black belt are one entity covering transactional, technical, and manufacturing areas.) The difference is in the selection process for each, which will depend on the background of the individual group and the organization's needs. In the case of the actual outlines, we have tried to make that distinction. However, the reader will notice that there is a great overlap in the content. This is not incidental. It is on purpose, because all groups must have virtually the same understanding of what Six Sigma is all about. The difference is in the detail of that knowledge.

Furthermore, as we already mentioned, the reader will notice that the outlines for each of the training are short, in the sense that they are not very elaborative. Again, this is by design. We have tried to provide the structure of the content and we hope that the reader will turn to volumes one through six to obtain detailed information as needed. We also have tried not to give any examples or simulations in the outline because we hope that the reader will generate his own examples as they relate to his organization. (If you need to generate examples, you may want to use some from the individual volumes of this series.)

Specifically, this volume contains the following chapters:

Acknowledgments

We have come to the end of this series on *Six Sigma and Beyond* and I am indebted to so many individuals who have helped directly or indirectly along the way.

A series of volumes of this magnitude is necessarily based on a wide variety of original sources. While I have made original contributions in some specific areas of analysis, and certainly in the conceptual framework of the topic, the bulk of the material (i.e., SPC, DOE, Taguchi, project management, reliability, statistics and probability, value analysis and so many other topics) is based on or expanded from the contribution of others. I have very carefully shown the sources of these materials at the points they are discussed. I hope I have made no omissions.

I am indebted to The Six Sigma Academy, The Biometrika, Institute of Mathematical Statistics, CRC Press, Tennessee Associates, Marketing News, McGraw-Hill, John Wiley & Sons, Prentice Hall, Ford Motor Company, Thompson Learning, Houghton Mifflin Company, American Supplier Institute, Mr. D. R. Bothe, and Dr. E. Buffa for granting me permission to use their material throughout these volumes.

Special thanks to the people at CRC for helping me throughout this project in making the material presentable. You all are great!

Thanks also to the hundreds of seminar participants and graduate students at Central Michigan University who over the years have helped in defining some of my thoughts and clarifying others. These two sources have indeed been the laboratory for many of my thoughts and approaches. Based on their contribution I have modified and changed quite a few items for the better. I am indeed grateful.

My special thanks, however, are reserved for my family and especially my wife. Through her support and encouragement I was able to do this project without any reservation and difficulty. Thank you.

About the Author

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Dr. Stamatis is a certified quality engineer for the American Society of Quality Control, a certified manufacturing engineer for the Society of Manufacturing Engineers, and a graduate of BSI's ISO 9000 lead assessor training program. He is a specialist in management consulting, organizational development, and quality science and has taught these subjects at Central Michigan University, the University of Michigan, and Florida Institute of Technology.

With more than 30 years of experience in management, quality training, and consulting, Dr. Stamatis has served and consulted for numerous industries in the private and public sectors. His consulting extends across the United States, Southeast Asia, Japan, China, India, and Europe. Dr. Stamatis has written more than 60 articles and presented many speeches at national and international conferences on quality. He is a contributing author in several books and the sole author of 20 books. In addition, he has performed more than 100 automotive-related audits and 25 preassessment ISO 9000 audits, and has helped several companies attain certification. He is an active member of the Detroit Engineering Society, the American Society for Training and Development, the American Marketing Association, and the American Research Association, and a fellow of the American Society for Quality Control.

Tables

Frequent Abbreviations in Six Sigma Methodology

ANOVA	Analysis of variance
COPQ	Cost of poor quality
COQ	Cost of quality
Cp	Short-term process capability
Cpk	Long-term process capability
CT	Critical to (matrix)
CTC	Critical to customer
CTD	Critical to delivery
CTP	Critical to process
CTQ	Critical to quality
CTS	Critical to satisfaction
CTX	Critical to process
CTY	Critical to product
D	Observed defects
df	Degrees of freedom
DOE	Design of experiment
DPO	Defects per opportunity
DPU	Defects per unit
DVP	Design validation (verification) plan
EVOP	Evolutionary operation
EVP	Engineering validation plan
EWMA	Exponential weighted moving average
FMA	Failure mode analysis
FMEA	Failure mode and effect analysis
GR&R	Gage repeatability and reproducibility
J	Units scrapped
KPIV	Key process input data
KPOV	Key process output data
LCL	Lower control limit
LSL	Lower specification limit
m	Opportunities per unit
MCP	Manufacturing control process
m.tot	Opportunities submitted
MTBF	Mean time between failure
OA	Orthogonal array
P-diagram	Parameter diagram
PLEX	Planning experiment

PPM	Parts per million
PTAR	Plan-Train-Apply-Review
PVP	Process validation plan
QFD	Quality function deployment
R	Units repaired
RSS	Root sum of squares
S	Units passed
SIPOC	Supplier-Input-Process-Operation-Customer
SOP	Standard operating procedures
SPC	Statistical process control
SPM	Statistical process monitoring
SS	Sum of squares
SSBB	Six Sigma black belt
SSC	Six Sigma champion
SSGB	Six Sigma green belt
SSMBB	Six Sigma master black belt
TDPO	Total defect per unit
TOP	Total opportunities
U	Units submitted
UCL	Upper control limit
USL	Upper specification limit
WIP	Work in process
Y.A	Annual rate of improvement
Y.final	Final throughput
Y.ft	First time yield
Y.M	Monthly rate of improvement
Y.m	Yield per opportunity
Y.normal	Normalized yield
Y.rt	Rolled-throughput yield
Z.lt	Long-term sigma
Z.shift	Shift factor
Z.st	Short-term sigma

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Part I

Understanding Adult Training and Instructional Design

Introduction

In 400 B.C., the Greek playwright Sophocles said, "You must learn by doing the thing, though you think you know it, you have no certainty until you try."

So it is with Six Sigma methodology. Many claim to know it, and others claim they have done it. The fact of the matter is, however, that inconsistencies exist in Six Sigma implementation, training, and results. This is partly due to the fact that, as of this writing, there still is no recognized body of knowledge (BOK) (the reader should be aware that the published American Society for Quality (ASQ) and others, including the author's, that have attempted to identify the BOK have not been met with 100% acceptance, including as regards certification). In addition, Six Sigma methodology is to a certain extent enshrouded in mystique. It is hoped that we will help diffuse this mystique and present the implementation and training in a format that many can use. We start by focusing on diffusion.

WHAT IS DIFFUSION?

Diffusion is the process by which an innovation is communicated through certain channels over time among members of a social system. (In our case, the social system is the organization). It is a special type of communication in that the messages are concerned with new ideas. Communication is a process in which participants create and share information with one another in order to reach a mutual understanding. (In our case, the mutual understanding is twofold: a) customer satisfaction and b) organizational profitability, however defined.) This definition implies that communication is a process of convergence (or divergence) as two or more individuals exchange information in order to move toward each other (or apart) in the meanings that they ascribe to certain events. (In our case, it is hoped that the issue of convergence will be the predominant factor for improvement.) We think of communication as a two-way process of convergence, rather than as a one-way, linear act in which one individual seeks to transfer a message to another. Such a simple conception of human communication may accurately describe certain communication acts or events involved in diffusion, such as when a change agent seeks to persuade a client to adopt an innovation. But when we look at what came before such an event and at what follows, we often realize that this sort of communication is only one part of a total process in which information is exchanged between the two individuals. For example, the client may come to the change agent with a problem or need, and the innovation is recommended as a possible solution. And if we look at the change agent–client interaction in a broader context, we may see that their interaction continues through several cycles and is indeed a process of information exchange. (In our case, the agent is generally the sponsor/champion, and the interaction is between master black belts, black belts and green belts.)

Thus, diffusion is a special type of communication in which messages are concerned with a new idea. (In our case, the new idea is the Six Sigma methodology.) It is this newness of the idea in the message content of communication that gives diffusion its special character. The newness means that some degree of uncertainty is involved. Uncertainty is the degree to which a number of alternatives are perceived with respect to the occurrence of an event and the relative probability of these alternatives; it implies a lack of predictability, structure, and information. In fact, information represents one of the main means of reducing uncertainty. That is why when dealing with a given level of Six Sigma in any capacity there must be open communication. Information is the difference in matter–energy that affects uncertainty in a situation where a choice exists among alternatives (Rogers and Kincaid, 1981, p. 64). (Information reduces uncertainty. Communication is the exchange of information. Furthermore, communication diffuses anxiety and fear and, above all, encourages participation and ownership.)

Diffusion is a kind of social change, defined as the process by which alteration occurs in the structure and function of a social system. When new ideas are invented, diffused, and adopted or rejected, leading to certain consequences, social change occurs. (In our case, we expect change — a positive change. In fact, we expect a breakthrough change in both customer satisfaction and organizational profitability.) Of course, such change can happen in other ways, too, for example, through a political revolution or through a natural event like a drought or earthquake. The reader will notice that we use diffusion and dissemination interchangeably, although some will disagree as to their meaning, because the distinction often is not very clear in actual practice. The general convention is to use the word *diffusion* to include both the planned and the spontaneous spread of new ideas. (To be sure, any Six Sigma initiative is indeed planned and very rarely, if ever, unplanned.) But we do find it useful to distinguish between centralized and decentralized diffusion systems. In a centralized diffusion system, decisions about such matters as when to begin diffusing an innovation, who should evaluate it, and through what channels it should be diffused are made by a small number of officials or technical experts at the head of a change agency. In a decentralized diffusion system, such decisions are more widely shared by the clients and potential adopters; here, horizontal networks among clients are the main mechanism by which innovations spread. In fact, in extremely decentralized diffusion systems, there may not be a change agency; potential adopters are solely responsible for the self-management of the diffusion of innovations. New ideas may grow out of the practical experience of certain individuals in the client system rather than come from formal research and development activities.

CHARACTERISTICS OF INNOVATIONS

Just because something is new does not mean that a) it is better or b) people will accept it. The characteristics of innovations, as perceived by individuals, help to explain their different rate of adoption.

- *Relative advantage* is the degree to which an innovation is perceived as better than the idea it supersedes. The degree of relative advantage may be measured in economic terms, but social prestige factors, convenience,

and satisfaction are also often important components. It does not matter so much whether an innovation has a great deal of "objective" advantage. What does matter is whether an individual perceives the innovation as advantageous. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption.

- *Compatibility* is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters. An idea that is incompatible with the prevalent values and norms of a social system will not be adopted as rapidly as an innovation that is compatible. The adoption of an incompatible innovation often requires the prior adoption of a new value system.
- *Complexity* is the degree to which an innovation is perceived as difficult to understand and use. Some innovations are readily understood by most members of a social system; others are more complicated and will be adopted more slowly. In general, new ideas that are simpler to understand will be adopted more rapidly than innovations that require the adopter to develop new skills and understandings.
- *Trialability* is the degree to which an innovation may be experimented with on a limited basis. New ideas that can be tried on the installment plan will generally be adopted more quickly than innovations that are not divisible.
- *Observability* is the degree to which the results of an innovation are visible to others. The easier it is for individuals to see the results of an innovation, the more likely they are to adopt it

In the case of Six Sigma, all the characteristics are present and indeed qualify the Six Sigma methodology as an innovation. The relative advantage is that for the past several years many large companies have claimed tremendous gains in profitability and advantages over their competitors. In terms of compatibility, to implement Six Sigma your organization must already have in place a quality foundation, such as Total Quality Management, that it does not conflict with Six Sigma. As for complexity, Six Sigma is complex enough to require intensive training and a long-term commitment from management before results are apparent. As regards trialability, our experience indicates that companies that immerse themselves in Six Sigma encourage their black belts to identify small projects and visible projects. The reason projects are small and visible is that such projects ensure that the methodology delivers what people say about it and produces success stories. There is nothing better than your own success story. Finally, in terms of observability, early projects are very carefully screened and monitored for improvement and used to convince others in the organization.

THE PROCESS OF SIX SIGMA DIFFUSION IN THE ORGANIZATION

There is nothing more difficult to plan, more doubtful of success, or more dangerous to manage than the creation of a new organizational order. "Whenever his enemies have occasion to attack the innovator they do so with the passion of partisans, while

the others defend him sluggishly so that the innovator and his party alike are vulnerable." These words were written in 1513 by N. Machiavelli (*The Prince*), yet they are quite appropriate for today's organizational cultures — especially in the Six Sigma diffusion process.

To implement the Six Sigma methodology we must understand that that in itself is a process. The process is made of seven steps:

- *Initiation*. Management investigates whether or not they should adopt the methodology.
- *Agenda setting*. Management discusses the relevancy of internal problems and the benefits of the Six Sigma methodology. Another way of looking at this is through a trade-off analysis of the advantages and disadvantages that the Six Sigma methodology can offer the organization beyond the current system.
- *Matching*. Management agrees to give Six Sigma a try with specific objectives that fit the organization. This is the critical point, because it is here that the decision to adopt takes place.
- *Implementation*. All the events, actions, and decisions involved in installing the Six Sigma system in the organization are considered.
- *Redefining and restructuring*. This is also a critical point in the implementation process because modifications and organizational structures may be changed to accommodate the expected changes as a result of Six Sigma.
- *Clarifying*. This is the stage in the implementation process where more precise process definitions are needed for improvement. For example, a classic clarifying issue is the notion of understanding the "operational definition" and the "true" SIPOC model.
- *Routinizing*. This is the stage of a mature organization using Six Sigma methodology as an ongoing activity throughout the organization for major problems and design issues.

Our focus in this volume is the actual implementation process. Implementation in the context of Six Sigma is an issue of training, which is one of the most important characteristics that distinguishes Six Sigma from any other program. What makes it special is both the amount of time required and the financial outlays associated with preparing an organization to tackle problems of improvement. Therefore, in this volume, we are going to discuss how to maximize learning using some of the latest theories and approaches of instructional design; in addition, we will present comprehensive requirements and outlines for appropriate and applicable training for each level of Six Sigma. Finally, we will also discuss the application of specific tools in the DMAIC as well as in the DCOV models.

REFERENCE

Rogers, E. M. and Kincaid, D. L. (1981). *Communication networks: toward a new paradigm for research.* Free Press. New York.

1 Understanding the Learner and Instruction

EXPECTATIONS FOR PARTICIPANTS

Education is the single greatest investment you will ever make in implementing the Six Sigma methodology. This education will give you the potential to alter your perceptions, thinking, and behaviors; it may also empower you to choose work and interests that will add additional meaning to your career life as well as to the organization's culture. Like all endeavors paying a high dividend, the personal cost of attaining higher learning is considerable. Every participant must contribute time, resources, and energy. The following recommendations are intended to help you maximize your investment in this lengthy process.

PREPARE FOR SUCCESSFUL LEARNING

Approach learning experiences with an open mind, set challenging goals, and monitor your progress.

- Familiarize yourself with the goals and objectives of your specific program.
- Set challenging goals for your own learning:
  - Create a personalized study plan for your training program and the individual material of the course in which you enroll.
  - Periodically assess progress using self, instructor(s), and peer feedback (take advantage of other similar courses that may help in your training. For example: DOE, Powerpoint presentation, statistical software, and so on).
  - Schedule frequent, self-paced study sessions with fellow participants or the instructor — or even the champion and even the master black belt. They are there to help you. Use them!

Take a personal approach to learning

- Reflect on your own thinking, learning, and prior experiences.
- Relate outside activities to course material and training activities.
- Analyze how new information relates to existing knowledge.
- Clarify your thinking and the assimilation of new knowledge by asking your instructors questions and actively participating in classroom discussions, online chat-rooms, or e-mail discussion lists — if available.

Seek and understand scholarly research

- Use libraries and other information sources, including the organization's library. This is not as bad as it sounds. Sometimes we do have to do some kind of research to find information about our customers, competitors, and the market and, of course, to track down technical information.
- Develop proficiency in the use of library research databases and especially your own organization's databases for things gone wrong, things gone right, warranty, things learned, and so on.
- Acquire the ability to critically assess the quality and validity of the information sources you use.
- Actively integrate scholarly knowledge and research evidence into training discussions and course assignments; after all, one of the objectives in Six Sigma is to introduce new tools, when appropriate and applicable, to solve problems.
- Learn how to compose a research paper or complete a research project including selection of appropriate topics and resources, a literature review, and the proper citation of references. This can be very helpful if you are assigned to a DFSS project and you are trying to identify the "ideal function."

PREPARE FOR EACH TRAINING COURSE

Know the rules

- Review the objectives for the course and any policies regarding class participation, attendance, overdue assignments, and make-up project assignments.
- Ask how much work will be expected of you (e.g., in and out of class, assignments, projects, and so on) and arrange your work/study schedule accordingly.

Know course materials

- Take advantage of periodic classroom reviews of previously covered content.
- Seek additional learning resources to fill any knowledge gaps and expand your understanding of course content.
- Realize that meeting course objectives often entails knowledge of material not directly mentioned by the course instructor or included in course materials. For example, DOE, software manipulation, and many specific objectives that may be required to pursue Six Sigma.

Build effective working relationships with your instructors, other black belts, master black belts, and champion, as well as other participants.

- View your instructors as "facilitators," offering guidance and feedback on your personal learning process.
- Seek additional contact and communication with your instructors, other black belts, master black belts, and champion, as well as other participants to enrich the learning experience.
- Be tolerant of opposing views and treat others with respect and civility.
- Seek support and advice from your instructors, peers, other black belts, master black belts, and mentors.

ASSUME AN ACTIVE ROLE IN THE LEARNING ENVIRONMENT

Bring awareness and a sense of purpose:

- Expect to earn your "grade."
- Attend all class sessions, including all scheduled activities. Try to minimize, if not avoid, all double scheduling during the training hours.
- Maintain compliance with any and all project deadlines.
- Meet expectations regarding project integrity (cost, measurement, capability, etc. are some of the issues we all like to cut corners with).

Bring knowledge, perspectives, and interest:

- Actively participate in class activities.
- Complete all required reading assignments prior to each class meeting and read suggested material.
- Expect your ideas to be challenged and prepare to support them with facts, research evidence, and expert judgment, whether discussing concepts online, asynchronously, or in the classroom.

Participants and the project assignment

- Meeting recommended deadlines for completing required assignments and projects.
- Participating in all scheduled virtual or asynchronous classroom discussions or working directly with the instructor to negotiate a suitable alternative.
- Taking advantage of optional learning activities, suggested readings, and opportunities for informal virtual or asynchronous communication with the course faculty and fellow students.

UNDERSTANDING ADULT LEARNERS

To be effective in any educational endeavor one must understand the learner. However, the adult learner has quite a few idiosyncrasies that are not present with the child learner. Perhaps the most important one is the fact that the adult learner views learning as a means to an immediate end. In other words, the adult learner wants to learn things as they pertain to his work "right now." Learning is more application-driven than theoretical. As a consequence, in this part of the book we are going to provide a very general overview of some of the issues and concerns in understanding the learner, the material, and, above all, the instructional process. For more information on adult learners, see Wlodkowski (1985), Cross (1981), Wonder and Donovan (1984), Knox (1986), and Brookfield (1986).

TO START WITH, WE MUST RECOGNIZE THAT ADULTS ARE INTERESTED IN

- Enhancing proficiency at a given task (work-related)
- Development and learning — recognition that different learners learn at different paces and with different methods (learning style, change events, responding to learner's diversity, occasions for new learning)
- Influencing participation by impulsive questioning and answering

The instructor or facilitator, therefore, must make sure that the following are observed at all times, so that learning may be enhanced.

- Respect
- Reasons
- Options
- Making learning relevant to their experiences

Every one of these items may contribute to learning; however, in specific terms, all these may be derived through appropriate and applicable tasks in the following:

- Procedures presentations
- Active learning
- Meaning
- Variety
- Stages of the program
- Affective and cognitive elements
- Interpersonal relationships
- Past and future purposes
- Support and challenge
- Models
- Self direction for learners
- Feedback
- Flexibility

This is not as easy as it sounds. However, if one were to use the principles of Instructional Design, the instruction becomes very systematic and productive. The idea of Instructional Design is based fundamentally on the SKA model. The SKA model focuses on three areas.

- *S*kill (Have you…?)
- *K*nowledge (Do you…?)
- *A*bility (Can you…?)

Therefore, to bring out the "best" in a participant, the instructor or facilitator must apply managerial skills in the instruction itself. Managerial skills are known as events of instruction (Gagne and Briggs, 1979). The more these events are understood by the instructor or facilitator, the better the instruction, the better the comprehension of the participant, and the more effective the overall training. The events are:

- Gaining attention — reception of patterns of neutral impulses
- Informing the learner of the objective — activating a process of executive control
- Stimulating recall of prerequisite learning — accessing working memory
- Presenting the stimulus material — emphasizing features for selective perception
- Providing "learning guidance" — encoding material semantically
- Eliciting performance — activating a response organization
- Providing feedback about performance correctness — establishing reinforcement
- Assessing performance — activating retrieval; making reinforcement possible
- Enhancing retention and transfer — providing cues and strategies for retrieval

An example of how these nine events may be used as part of the instruction is shown in Table 1.1. This table associates the nine events with the five basic types of learned capabilities. For more information on the conditions of learning, see Gagne (1977) and Travers (1982).

In the case of Six Sigma training, all these play an important role since the people who are undergoing the training may have different experiences and certainly different backgrounds as well as education. Because of these differences the educational/training implications must be focused on three areas:

- Planning for learning
- Managing learning
- Instructing

In the course of Six Sigma training, it will be necessary to consider at least two methods of instruction. The first is the group presentation in which a facilitator or

TABLE 1.1
Instructional events as they relate to the five types of learned capability

	Type of Capability				
Instructional Event	**Intellectual skill**	**Cognitive skill**	**Information**	**Attitude**	**Motor skill**
Gain attention	Introduce stimulus change; variations in sensory mode				
Informing learner of objectives	Provide description and example of the performance to be expected	Clarify the general nature of the solution expected	Indicate the kind of verbal question to be answered	Provide example of the kind of action choice aimed for	Provide a demonstration of the performance to be expected
Stimulating recall of prerequisites	Stimulate recall of subordinate concepts and rules	Stimulate recall of task strategies and associated intellectual skills	Stimulate recall of context of organized information	Stimulate recall of relevant information, skills, and human model identification	Stimulate recall of executive sub routine and part skills
Presenting the stimulus material	Present examples of concept or rule	Present novel problems	Present information in prepositional form	Present human model, demonstrating choice of personal action	Provide external stimuli for performance, including tools or implements
Providing learning guidance	Provide verbal cues to proper combining sequence	Provide prompts and hints to novel solution	Provide verbal links to a larger meaningful context	Provide for observation of model's choice of action, and of reinforcement received by model	Provide practice with feedback of performance achievement

Eliciting the performance	Ask learner to apply rule or concept to new examples	Ask for problem solution	Ask for information in paraphrase, or in learner's own words	Ask learner to indicate choices of action in real or simulated situations	Ask for execution of the performance
Providing feedback	Confirm correctness of rule or concept application	Confirm originality of problem solution	Confirm correctness of statement of information	Provide direct or vicarious reinforcement of action choice	Provide feedback on degree of accuracy and timing of performance
Assessing performance	Learner demonstrates application of concept or rule	Learner originates a novel solution	Learner restates information in paraphrased form	Learner makes desired choice of personal action in real or simulated situation	Learner executes performance of total skill
Enhancing retention and transfer	Provide spaced reviews including a variety of examples	Provide occasions for a variety of novel problem solutions	Provide verbal links to additional complexes of information	Provide additional varied situations for selected choice of action	Learner continues skill practice

an instructor leads the presentation of the material through small or large group activities by way of lectures, discussion simulations, etc. The second, and somewhat less frequent in Six Sigma, is the individualized approach to instruction. Here the participant may work independently at a self pace. This approach is self-centered and learner-determined based on specific situations. Typical delivery systems and related information are shown in Table 1.2.

PRINCIPLES OF INSTRUCTIONAL DESIGN

Now that we have reviewed some of the instruction systems, let us examine the actual instructional design process. For extensive information on instructional design, see Briggs (1977), Richey (1986), Reigeluth (1987, 1983), Seels and Richey (1994), Dick and Carey (1978).

- Instruction is a human undertaking whose purpose is to help people learn
- Instruction is a set of events which affect learners in such a way that learning is facilitated

Therefore, instruction must be planned to accomplish:

- The aiding of learning
- Immediate and long range goals (we are focusing on transferring knowledge)
- Human development (no one is educationally disadvantaged)
- System approach (analysis of need or goals to evaluation)

STAGES OR PHASES OF DESIGN

As with anything else, there is a process that one must follow to facilitate learning. That process is called instructional design and it has ten phases. They are:

- Front-end analysis
- Task analysis
- Product survey
- Design instruction
- Design of job aids
- Development of material
- Evaluation
- Delivery of materials
- On the job application
- Evaluation

We are going to address all of them, with the exception of phases 3 and 5. The reason for this is that in both cases the application to Six Sigma is very straightforward and contains no bottlenecks or unusual problems. The product is already

known, and the instructional aids simply consist of handouts of statistical formulas with their application or perhaps special forms.

In all cases, the instructional design may also be subdivided into levels, such as system, course, and lesson, with each one having different requirements and instructional characteristics.

System level may be interpreted as a curriculum. In Six Sigma training, the system is the entire methodology — from the requirements of the executive, to the champion, to the master black belt, to the black belt, and to the green belt. The requirements under the system are to develop

- Analysis of need, goals, and priorities
- Analysis of resources, constraints, and alternatives to the delivery system
- Determination of scope and sequence of curriculum and courses
- Delivery system design
- Trainer preparation
- Formative evaluation
- Pilot and revision
- Summative evaluation
- Installation and diffusion

Course level may be interpreted as the specific training of the executive, champion, master black belt, black belt, and green belt. Course-level requirements are

- Determining course structure and sequence
- Analysis of course objectives

Lesson level may be interpreted as the content of each course broken down on a daily basis. Lesson-level requirements are

- Defining performance objectives
- Preparing lesson plans (modules)
- Developing and selecting materials and media
- Assessing participant performance

Conditions of Learning

In order for anyone to learn, the instructor and or facilitator must be aware of the "learning process." Some of the issues here are

The association tradition associates learning with known items. This may be done through a) continuity (building on old knowledge or new knowledge systematically) or b) repetition of facts and items of interest. Repetition does not have to be boring and devoid of context. Rather, it may be conducted as a summary, review, Q and A, or in several other formats.

Trial and error is the most common and yet most inefficient form of instruction. Under this method, we try things as we go and constantly evaluate the outcome.

TABLE 1.2
Typical delivery systems and related information

Delivery System	Possible Media	Learner Activity	Methods, Teacher Roles
Group instruction	Books, other reading materials	Reading	Lectures
	Charts, chalkboard, displays	Listening	Discussions
	Teacher	Observing demonstrations	Demonstrations
	Guest speakers	Manipulating objects	Oral quizzing
	Real objects, models	Visits	Corrects papers
	Parts	Participating in simulation(s)	Evaluate results
	Overheads	Home study	Prepares reports
	Movies/videos	Exercises and projects	Field trips
Individualized instruction	Programmed texts	Reading	Placement testing
	Books	Responding	Diagnostic testing
	Modules	Self-pacing	Monitors progress
	Audio-visual devices	Self-checking	Remedial instruction

Small group	Books	Reading to each other	Assesses level of participant progress
	Exercises	Performing exercises	Forms small groups for specific lessons
	Simulation activities	Performing simulations	Evaluate exercises set up and results
	Slide/tape presentations	Discussion	Assesses overall progress
	Sound recordings	Watching presentations	Keeps records
	Completing team assignments	Assists in locating and using resources	Introduces new projects to group(s)
Independent study	Books	Reading and independent study	Advisor performs guidance function
	Libraries	Conducting library searches	Suggests or assigns tasks
	Reading lists	Reviewing lab experiments	Confers with learner upon request or as scheduled
	Laboratories	Writing papers	
	Learning centers and associated equipment and materials	Conferring with instructor	Conducts evaluations of progress
Work related	Any or all of the above for study portion of program	Any or all of the above for study portion of program	Any or all of the above for study portion of program
	Work at specified locations	Any assigned work function, under supervision	Coordinates work assignment with study portion of program
	Involves variety of persons and equipment as media		
Home study	Books	Home study by reading, completion of exercises	Assigns materials, exercises, and evaluates exercises
	Modules		
	References	Communications with instructor	May prepare and mail supplementary materials

Our evaluation of achievement is based on positive reinforcement in accordance with the expectations and objectives we have set.

Conditioned response is a very common approach to instructing for "learning," as it appears simple and harmless. But it is neither. It presupposes magical powers on the part of the instructor or facilitator to a) interpret voluntary and involuntary responses from the participants and b) figure out the learner's "insight." This implies that the instructor or facilitator knows the participant's optimal learning style. The possibilities are the holistic (Gestalt learning) approach and the participant's prior learning ability and benchmark. While both approaches are acceptable, the instructor or facilitator must be cognizant of both and use them as necessary. Remember, different people learn differently for many reasons.

The second item of concern for conditioned response is the presumption that the participant learns through verbal associates (memorization). This may be a very serious problem (in fact, a trap) in the Six Sigma methodology, especially since many formulas must be learned. We recommend that the instructor not rely on memorization but employ repetition exercises. This is a much better approach, and in the long run, the participant is better equipped to transfer the learned information outside of the classroom environment.

Miscellaneous: the primary concern here is motivation. The instructor's (external condition) as well as the participant's (internal condition) motivation has a lot to do with learning. For example, if the "learning event" is the central focus of our experience, then the external factors will be: a) continuity, or the temporal arrangement of conditions, b) repetition, and c) reinforcement, or the arrangement of contingencies. Note that none of these factors is learner-dependent. In fact, each one is dependent on the instructor or facilitator. In contrast, internal factors are dependent on the learner and represent a) factual formation, i.e., they may be presented or recalled from prior learning, b) intellectual skills, in that they are recalled from prior learning, and c) strategies, i.e., they are self-activated from prior practice and or experience. Note that none of these is instructor-dependent. The learner associates previous experience and learning with current material. The richer the experiences, the more pleasant and value-added the current material and knowledge.

So why do we bother with the above items? What is their relation to Six Sigma training? It turns out that the above conditions of learning are inherently important in Six Sigma, because Six Sigma methodology provides some very challenging items for the instructor and facilitator in the areas of "learning capability." They are:

1. Intellectual skills (demonstrating symbol use)
   - Discrimination (distinguish)
   - Concrete concept (spatial relation)
   - Defined concept (using a definition, clarification occurs)
   - Higher-order rule (combination)
2. Cognitive strategy (efficient use of recalling or solving a problem)
3. Verbal information (recall)
4. Motor skill (action)
5. Attitude

TABLE 1.3
Standard verbs to describe learning capabilities

Capability	Capability Verb	Example (Action Verb in Italics)
Intellectual Skill		
Discrimination	DISCRIMINATES	discriminates, by *matching* French sounds of "u" and "ou"
Concrete Concept	IDENTIFIES	identifies, by *naming* the root, leaf, and stem of representative plants
Defined Concept	CLASSIFIES	classifies, by using a *definition,* the concept "family"
Rule	DEMONSTRATES	demonstrates, by *solving* verbally stated examples, the addition of positive and negative numbers
Higher-order Rule (Problem Solving)	GENERATES	generates, by *synthesizing* applicable rules, a paragraph describing a person's actions in a situation of fear
Cognitive Strategy	ORIGINATES	originates a solution to the reduction of air pollution by *applying model* of gaseous diffusion
Information	STATES	states orally the major issues in the development of the Six Sigma methodology
Motor Skill	EXECUTES	executes *backing* a car into driveway
Attitude	CHOOSES	Chooses *playing golf* as a leisure activity

Table 1.3 provides some very simple examples of standard verbs to describe learning capabilities.

On the other hand, a motivating or an enthusiastic instructor plays a major role in the learning ability of the participant. Some characteristics and skills of motivating instructors are:

- They know something beneficial for adults
- They know the subject matter well
- They are prepared to convey their knowledge through an instructional process
- They have a realistic understanding of learners' needs and expectations for what they are offering them to learn
- They have adapted the instruction to the learners' level of experience and skill development
- They continually consider the learners' perspective
- They care about and value what they teach, both for themselves as well as for the learners
- This commitment is expected in the instruction with appropriate degrees of emotion, animation, and energy
  - rapid, uplifting, varied vocal delivery
  - dancing, wide-open eyes
  - frequent, demonstrative gestures
  - varied, dramatic body movements
  - varied, emotive facial expressions

- selection of varied words, especially adjectives
- ready, animated acceptance of ideas and feelings
- exuberant overall energy level

The benefits of a motivating instructor or facilitator are demonstrated in the instruction process through the creation of a positive attitude. A motivating instructor:

- Shares something of value with her learners
- Concretely indicates her cooperative intentions to help adults learn
- Reflects, to the degree authentically possible, the language, perspective, and attitudes of her learners
- Gives her rationale when issuing mandatory assignments or training requirements
- Allows for introductions
- Eliminates or minimizes any negative conditions that surround the subject
- Ensures successful learning
- Makes the first experience with the subject as positive as possible
- Positively confronts the possible erroneous beliefs, expectations, and assumptions that may underlie a negative learner attitude
- Associates the learner with other learners who are enthusiastic about the subject
- Encourages the learner
- Promotes the learner's personal control of the learning context
- Helps learners to attribute their success to their ability and effort
- Helps learners to understand that effort and persistence can overcome any obstacles when learning tasks are suitable to their ability
- Makes the learning goal as clear as possible
- Makes evaluation criteria as clear as possible
- Uses models learners can relate to when demonstrating expected learning
- Announces the expected amount of time needed for study and practice for successful learning
- Uses goal-setting methods
- Uses contracting methods

DESIRABLE SEQUENCE CHARACTERISTICS ASSOCIATED WITH FIVE TYPES OF LEARNING OUTCOME

We have been discussing the learner and some of the issues and concerns of the instructional process. In Table 1.4, we summarize some of the desirable sequence characteristics, so that the instruction may be fruitful and appreciated by the participant.

In conjunction with the desirable sequence, there is also a decision cycle of training that must be developed. In the case of Six Sigma, the decision is pretty straightforward, but let us summarize some key points of the general process.

TABLE 1.4
Desirable sequence characteristics associated with five types of learning outcome

Type of learning outcome	Major principles of sequencing	Related sequence factors
Motor Skills	Provide intensive practice on skills of critical importance and practice on total skill.	First, learn the executive routine (rule).
Verbal Information	For major subtopics, order of presentation is not important. Individual facts should be preceded or accompanied by meaningful context.	Prior learning of necessary intellectual skills involved in reading, listening, etc. is usually assumed.
Intellectual Skills	Presentation of learning situation for each new skill should be preceded by prior mastery of subordinate skills.	Information relevant to the learning of each new skill should be previously learned or presented in instructions.
Attitudes	Establishment of respect for source as an initial step. Choice situations should be preceded by mastery of any skills involved in these choices.	Information relevant to choice behavior should be previously learned or presented in instructions.
Cognitive Strategies	Problem situations should contain previously acquired intellectual skills.	Information relevant to solution of problems should be previously learned or presented in instructions.

Table 1.5 shows the decision cycle, and Table 1.6 shows the different routes of payoff to the organization. Again, these two tables are shown here so that the reader may appreciate the complexity of training in deciding what is proper and what the payoff is to the organization. Specifically, under Six Sigma, the decision is generally made by top executives in the organization, and the payoff is hoped to be demonstrated in increased customer satisfaction and profitability for the organization.

Perhaps one of the most contested topics in training for the last several years has been the effectiveness of training. That means that as training progresses and draws to a close, the question of whether or not the training is meeting or has met the objectives or was beneficial and to what degree is asked. There are two basic evaluations. The first one is the *formative*, which is an ongoing evaluation of the training to ensure that everything fulfills the objectives. It is conducted during the development of the training. The second is the *summative* evaluation, which is performed at the end of the training and focuses on whether or not the objectives were met. Obviously, there are many ways to evaluate the training, but the classic evaluation is Kirkpatrick's Hierarchy of Evaluation model. What Kirkpatrick did was to separate the various outputs of training and evaluate them separately. Level 1 is the weakest, for it evaluates based on perception of "likes" and "dislikes." In other words, it focuses on learner reactions. Level 2 focuses on learning, and level

TABLE 1.5
Decision cycle

The logical steps	Some key decisions
Goals for HRD that will be worthwhile to the organization are established	Is there a worthwhile problem or opportunity to be addressed? Is the problem worth solving or addressing? What organizational benefits could HRD produce? Can HRD help? Is HRD the best solution? Who should receive HRD? What SKA are needed?
A workable program design is created	What learning processes will best produce needed SKA? Is a design already available? Can an effective design be created? Is it likely to work?
A program design is implemented and made to work	What is really happening? Has the design been installed as planned? Is it working? What problems are occurring? What changes should be made?
Recipients exit with new SKA; enough HRD has taken place	Who has and has not acquired SKA? What else was learned? Are SKA sufficient to enable on-the-job usage?
Recipients use new SKA on the job or in personal life; reactions to HRD are sustained	Have HRD effects lasted? Who is using new SKA? Which SKA are and are not being used? How are SKA being used? How well are SKA being used?
Usage of SKA benefits the organization; original HRD needs are sufficiently diminished	What benefits are occurring? What benefits are not occurring? Are any problems occurring because of new SKA use or nonuse? Should HRD be continued? Should less be done? More? Are revisions needed? Was it worth it?

3 focuses on job application. On the other hand, level 4 is the strongest and most difficult to perform; it is also the most valuable. Evaluation is based on the objectives of the training in relation to results. It focuses on the following questions.

- Should I conduct a level 4 evaluation? (An issue of cost and effectiveness.)
- Is a level 4 study feasible? (How would I go about validating and correlating the data of training and implemented benefit?)
- Which design should I use? (Specifically, what do I want to measure?)
- What will the training cost?
- How will I analyze the data?
- How will I report the results?

TABLE 1.6
Different routes to organizational payoff

Training intervention	New SKA or reactions	Behavior change	Benefits to organization
Safety training	Awareness of and skill in following safety procedures	Greater adherence to procedures	Reduced injuries and lost time
Conflict resolution	Skill and knowledge in methods	Use of techniques when called for	Reduce conflict in the workplace; increase productivity, morale, and commitment to organization
Six Sigma training Black belts Green belts	Appropriate level of skill and knowledge in tools and methodology	Use techniques when called for	Improve customer satisfaction and profitability
FMEA	Skill and knowledge in the construction and analysis of the FMEA	Use the FMEA as a preventive tool to improve design and process	Reduce design and process defects
Mistake proofing	Skill and knowledge in the method of mistake proofing	Use mistake-proofing approaches to eliminate defects	Reduction of waste through appropriate mistake-proofing devices, and controls
Project management	Skill and knowledge in the theory and application of project management	Use project management methodology to improve budgets, delivery and scheduling	Reduce problems due to scheduling, budget, and delivery of specific projects and or products

A summary of that classification is shown in Table 1.7. Kirkpatrick's evaluation is also known as the four-level evaluation model. In the case of Six Sigma the outputs would be:

Level 1: Were the participants satisfied with the training? (material, instructor, environment, expectations, etc.)
Level 2: Can the participants demonstrate knowledge of what they learned? (In the Six Sigma methodology, this is measured by the progress toward the objective.)
Level 3: Are the skills of the Six Sigma methodology used beyond the specific assigned projects?
Level 4: Is customer satisfaction and profitability better off after the training? (For most of the training, this level is the most difficult to measure. However, for Six Sigma, it should be very easy since from the beginning this correlation was the driving force of the project itself.)

TABLE 1.7
Kirkpatrick's evaluation with several examples

Levels of evaluation	Job training	Nutrition education	Adult literacy
Level 4: Results (community or organizational impact)	Does output rise?	Do hospital admissions fall?	Does public library usage increase?
Level 3: Behavior (Transference of skills)	Are skills used in work?	Do food purchasing habits change?	Do learners read at home?
Level 2: Learning (demonstration of learning)	Do learners demonstrate their acquisition of skills?	Do participants show knowledge of good diet?	Do learners show mastery of reading and writing skills?
Level 1: Reaction (general evaluation)	Do learners express their satisfaction with the overall program?	Do participants express their satisfaction with the program?	Do participants of the training express their satisfaction with the program?

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2 Front-End Analysis

INTRODUCTION

The purpose of front-end analysis (FEA) is to find the most effective way to stimulate needed individual or organizational change. FEA is the first step in the instructional systems design (ISD) process, because it is critically important to become clearly aware of three major things:

- WHAT problem to solve (in the case of a problem solving FEA)
- WHAT new goals or directions to set (in the case of a planning FEA)
- HOW to achieve each of these most effectively

Traditionally, ISD has been applied to problems or gaps in performance that need solving. Performance gaps arise from differences between actual and desired performance. The intent is always to close the gap between the two.

FEA helps to locate any gaps between actual and desired performance. Your goal should be to reach desired performance levels. First, however, you must identify where you are. Then, you need to identify where you need to go. Finally, you must decide how to get there.

FEA addresses all these issues. FEA does not, however, assume the gap or problem is related to "training" or the solution related to "instruction." In fact, when using FEA you may find the problem is unrelated to instruction! *Only when your problem can be solved using instruction or job aids* will you design and develop instructional materials. FEA will clearly define for you such cases, saving you the costs of developing unnecessary instruction.

Generally, there are two different types of FEA. The first, and most common, FEA is the problem-solving FEA. It deals with finding performance gaps and their causes and solutions. In addition, it is a somewhat focused, short-term problem-solving approach that is used to isolate and address gaps that are the source of organizational problems. As such, it is very similar to the early stages of the Global Problem Solving Process, for which see volume 2 of this series.

FEA can also be used to identify and plan for completely new organizational goals and directions. This is in contrast to merely fixing existing systems. The planning FEA takes a systems approach to bringing about organizational change and in that way is similar to process improvement. It focuses on improvement of basically sound systems, rather than on short-term problem settlement. As such, the steps in the planning FEA duplicate the first steps in process improvement: 1) identify the opportunity and 2) define the scope (including stakeholders).

In the case of Six Sigma, we are more interested in the second approach, since we are about to embark on a completely new organizational directive. Thus, we are interested in determining our needs early so as to plan for future opportunities. Need can be addressed by using either the following problem-solving FEA steps or the process improvement methodology.

Since you are at the very beginning of the ISD process for the Six Sigma methodology, no formal preparation is required at this point. However, you do need to make a commitment to following systematic procedures. This is a definite departure from the more unstructured approach serving many instructional programs. Prepare yourself by eliminating any assumptions you may have about the problem. Find out whether instruction is the answer using FEA. In FEA, a commitment to following systematic procedures means not assuming a training problem but attempting to verify what type of problem really exists.

PROBLEM-SOLVING FRONT-END ANALYSIS

The steps for conducting a problem-solving FEA include the following: 1) identify the problem, 2) identify potential and actual causes, 3) identify potential solutions, 4) choose the best solutions, and 5) report your findings.

1) *Identify the problem*: in a problem-solving FEA, you are trying to locate and remedy gaps between actual and desired performance. Collect data on gaps using the techniques described in Table 2.1. Be sure to gather information from a variety of perspectives (e.g., job incumbents, supervisors, customers, etc.) to limit collection of biased information. In addition, examine current operations and current performance levels and define desired performance levels. The difference between the two is your gap or "problem" area. (NOTE: desired performance levels should be based on similar, "best-in-class" in-house operations.) Or, benchmark to similar operations outside the company.

   In defining the problem, aim to be as specific as possible. Focus on the who, what, where, and how often of the problem. Assign dollar values. For example, instead of stating "parts are being rejected too often" as the problem, be more specific:

   PROBLEM Rejection of parts from Line 5. This problem has occurred daily over the past 6 weeks, costing an estimated $7000 per week.

   Notice a dollar value has been assigned to the problem. In addition, you know where the problem is, what is happening, and how often. This allows you to assess whether the problem is worth further analysis. When defining the problem, also consider the following:
   - Have you thoroughly identified all gaps in performance?
   - What are the specific differences between actual and desired performance?

TABLE 2.1
Data collection techniques

Technique	Definition
ADVISORY GROUPS	Subject matter experts brought together to discuss various issues.
BRAINSTORMING	Small group discussions formed to generate ideas about a particular topic. Rules of discussion include: openness to each other's ideas, encouragement of far-fetched ideas, the more ideas the better, and zero negative evaluations.
CRITICAL INCIDENT REPORTS	Reports covering events that led to a particular event or problem. These reports offer facts, as opposed to opinions, about what happened.
DELPHI METHOD	A way of gathering information through a type of mall survey. Participants express opinions about a problem or opportunity. Opinions are collated to form a majority opinion list, which is redistributed through a series of mailings for reprioritization.
FOCUS GROUPS	Individuals brought together to discuss a particular issue. The purpose is to discover attitudes, ideas, possible barriers, etc.
INTERVIEWS (GROUP)	Face-to-face question-and-answer discussions among a group of individuals. Group interviews cost less than individual interviews, but allow for less depth in examining opinions and attitudes.
INTERVIEWS (INDIVIDUAL)	Face-to-face question-and-answer discussions using preset questions. Individual interviews allow for in-depth examination of opinions and attitudes but are costly.
NOMINAL GROUP METHOD	This method is comparable to a Delphi Method but in a group setting. Individuals write down and share in turn their opinions about problems, their causes, and solutions. The group rank orders opinions according to validity, etc.
OBSERVATION	A way to examine on-the-job behaviors using a preset checklist. The observer must be given direction on who, what, and how to observe. Observations can provide a wealth of information about what actually is occurring on the job.
QUESTIONNAIRES	A series of questions sent to a number of individuals seeking information on opinions, attitudes, facts, etc. about problems, causes, and potential solutions. Questionnaires take time to develop yet can reach many people in a short period of time. Questionnaires cost less than the interview or observation method, but may not delve deeply into any one area. All questions must relate to the information being sought.

- Have you attempted to break down complex gaps?
- Have you identified the jobs, operations, employees, etc. involved in the problem?
- Have you identified problem locations? Have you determined when the problem occurs?
- Do you know the problem's impact?
- Did you gather enough information from enough people to give you insight into the problem? Do you understand the culture in which the problem exists?

TABLE 2.2
Contributing factors to problems

Contributing Factors to Problems	Examine
TECHNICAL/WORK	Tools, equipment, material, work distractions
ENVIRONMENT	Workload distribution
	Temperature, illumination, ventilation
	General environment
	Technical inputs (engineering, systems, etc.)
ORGANIZATION	Standards, policies, practices, values
	Use of "systems" thinking
	Relationships (social, political, economic, employee, customer, supplier, etc.)
INDIVIDUAL	Interpersonal skills (teamwork, handling personality conflicts and communication problems, flexibility, cooperation, agreement with organizational goals, etc.)
	Skill and knowledge (knowledge of basic facts, concepts, principles, strategies, etc.)
SUPERVISION	Interpersonal skills
	Skill and knowledge
	Standards, policies, procedures
	Management skills (objective setting, team building, leadership, time and stress management, etc.)
	Support skills (recognition, feedback, reinforcement, modeling, mentoring, motivation)

In addition, determine if the problem is random or continuous. For example, if the problem occurs regularly, it may continue due to some cause in the organizational system. This is a continuous problem. In such cases, an FEA becomes a valuable problem-solving tool. If the problem is a one-time event, such as with a random problem, it would not be worth conducting an entire FEA.

2) *Identify potential and actual causes*: in this step, you need to identify the cause of the problem. What are the contributing factors to the problem? Consider technical, organizational, individual, and supervisory performance (see Table 2.2 for a list of possible contributing factors). Gather this information using the same techniques outlined above, using a variety of techniques and sources to avoid bias. (This step is similar to the who, what, why, where step in the global problem-solving process.) After listing several contributing factors, narrow the list to the *most likely* causes. Ask for assistance from others who understand the problem and probable causes.

   For example, suppose a supervisor from one of your manufacturing plants presents you with a problem: there are too many parts being rejected. You need to further define the problem. You then can begin to identify potential and actual causes.

Identify the problem: as you attempt to define the problem more precisely, you find the rejection problem is located on Line 5. You also find the problem has occurred over the last 6 weeks, on a daily basis. Thus, it's not a random problem but a continuous one. You also find the cost of the rejection problem to be an estimated $7,000 per week. Because the problem is continuous and costing large sums, you decide it is worthy of further investigation.

Identify potential causes: at this point, you can either guess at the potential causes, ask for opinions, or begin an in-depth investigation. You choose to look in depth at what has happened. You begin interviewing all those involved with the problem. You find the following:

- The in-plant handling of raw materials parts appears inadequate. Raw materials are haphazardly tossed into bins.
- The raw material supplier does not seem to be meeting the product blueprints given to them by Purchasing.
- The manufacturing process does not seem to support the product blueprints.

Identify actual causes: Because you have gathered "opinions" vs. facts, you now need to confirm which opinions are accurate. This will lead you to the actual causes. You find the following:

- First, a random sample of raw materials is examined before entering Line 5. You find raw materials are *passable.*
- Second, you find the supplier's product meets the product blueprints given to them by Purchasing. Supplier products are *passable.*
- *HOWEVER, reports show differences between the manufacturing process and what's required by the product blueprints.* The manufacturing process must support the product blueprints if a passable product is expected. For example, machines must be tooled to meet product blueprints, etc. You find this is not happening. You have located the actual cause. You may need to search further, however, for "less immediate" causes. Searching further into the actual cause, you find the department creating the product blueprints (Product Engineering) and the department creating the manufacturing process blueprints (Process Engineering) *do not meet or communicate on a regular basis*. Thus, there is no assurance that the manufacturing process will support the product blueprints. You also find that neither department operates on a "team basis;" they are not used to working together with other departments on a consistent, proactive basis.

3) *Identify potential solutions*: after defining the problem and finding related causes, you now need to solve the problem. Gather potential solutions through the same data collection procedures outlined earlier (in practice, you may collect data on all these questions at the same time). Often, solutions will flow directly from knowledge of causes. For example, continuing with the earlier problem, how would you solve it?

Identify solutions: essentially, you have two different types of causes requiring two different solutions:

- The immediate cause needing a solution is the difference between the product blueprints and the manufacturing process. Product blueprints and manufacturing processes *must* be compatible. You find this can be solved either by making product or manufacturing changes or by redesigning the part from scratch. You would need to perform a cost-benefit analysis on each potential solution before making a decision.
- The less-immediate cause needing a solution is the communication problem between the departments. (Yet this must be solved if future problems are to be eliminated.) Two solutions are available. First, biweekly meetings between department heads can be established. Second, each department can partake in a "team-building" instructional program. Such a program would foster open communication between other departments. You would need to perform a cost-benefit analysis on each potential solution before making a decision.

4) *Choose the best solutions:* how can you solve the problem? Can the problem be solved using education or training, or is something else needed? When choosing the best solution or solutions, you need to determine the suitability of each. Are the solutions realistic and affordable? Do they match the problem? Which is best? Consider the following factors when evaluating the feasibility of the solutions using a typical cost-benefit analysis:
   - Cost of the problem
   - Cost of the solution
   - How well the solution will solve the problem
   - Whether customers and stakeholders will accept and support the solution
   - Whether the solution is acceptable to the organization's culture
   - Whether the cost and time required fit the available resources
   - Whether there are barriers to implementing the solution, including delineation of each barrier.
   - Whether the solution is consistent with long-term objectives and continuous improvement
   - Potential return on investment

   By comparing potential solutions against these criteria you will be using *cost-benefit analysis* to link your solution to strategic business goals. Frequently, instruction *will not* be the optimal solution. In our example, the immediate cause did *not* require instruction. Yet the less immediate cause could require education or training.

   FEA can enhance the professional image of education and training. When instructional solutions are used only when supported by data, the results will be far more positive. Too often, instructional programs are "thrown" at problems when the best solution lies in another area.

   Choose the best solutions: based on your cost-benefit analysis, you can choose the best possible solution. You may find a solution is not feasible because of limited funds, timing, potential barriers, etc. When this happens, you may need to modify your chosen solutions to fit your constraints.

TABLE 2.3
Front end analysis report information

Title	Specifics
INTRODUCTION	Describe how and why the FEA process began. Describe procedures used to locate and confirm flaps, causes, and solutions.
FINDINGS	Discuss flaps identified, causes, operating consequences, personnel, jobs, and costs involved.
POSSIBLE SOLUTIONS	Describe solutions requiring no action, action involving instruction or job aids, and action not involving instruction or job aids. Compare solutions and discuss problems associated with each solution.
RECOMMENDED SOLUTIONS	Detail chosen solution and how to measure or determine success. Give rationale for choice. Identify population, jobs, and costs involved. Discuss relationship to organizational objectives and benefits.
CONTINUOUS IMPROVEMENT	Describe how the solutions will support continuous improvement objectives.
PROTECT SCOPE AND SCHEDULE	Describe scope of project. Identify constraints, required resources, and estimated schedule. Identify customer and client relationships. Suggest measures or definitions of "success."
APPENDICES	Back up correspondence, budgets, data gathering tools, raw data, outside sources, etc.

The worst scenario would be having to develop new solutions because of constraints found in the cost-benefit analysis.

5) *Report your findings*: report the information from your FEA in a report that includes the information shown in Table 2.3. Proceed to the next step in the ISD process, task analysis, *only if your analysis has shown instruction to be an appropriate solution.* Otherwise, explore other interventions. These could include organizational restructuring, organizational development, etc.

After you have completed your FEA, evaluate the quality of your efforts by using a formative evaluation. A typical check list for such an activity is shown in Table 2.4.

TASK ANALYSIS

Task analysis is performed when trying to determine what you want out of — and want to put into — an instructional program. Task analysis data become the foundation for the entire ISD process.

TABLE 2.4
Front end analysis formative evaluation checklist

ASK YOURSELF THESE QUESTIONS: Each of the following questions is addressed under major headings in this phase. Any "NO" answer should serve as an alarm that your FEA process needs improvement!	**Y**	**N**
1. Does your situation call for a problem-solving FEA? (If so, you should have followed the steps outlined in this phase.)		
2. Does your situation call for a planning FEA? (If so, you should have followed process improvement methodology.)		
3. Have you used a variety of information-gathering techniques and sources to identify your performance gaps or problems?		
4. Have you defined the problem as specifically as possible, focusing on observable, measurable outcomes with assignable dollar values when possible?		
5. Have you established whether the problem is random or systematic?		
6. Have you gathered information to identify potential and actual causes of performance gaps?		
7. Have you generated a comprehensive list of potential solutions to the problem?		
8. Have you systematically evaluated potential solutions, using a cost-benefit approach, to select the most appropriate ones?		
9. Have you summarized your FEA information in a report?		

Task analysis will identify everything someone would need to expertly perform a particular job, skill, or function. For example, consider the job of changing a tire. Task analysis would identify all the steps involved in changing a tire. This would include who performs what and when, using what tools, and under what conditions. Task analysis data becomes vital when deciding what other performers should know if they, too, are to become "experts." Essentially, this is how instructional content is formed. In the case of Six Sigma methodology, this is a very critical stage in the process because, depending on what level the instruction is for, the requirements will change quite drastically. This will be discussed in greater detail in Part II of this volume. *Only when* your FEA has indicated a need for instruction, and only after management has approved of the instruction, is task analysis started. Task analysis is a highly structured process and can often be time-consuming and expensive. To move from FEA to task analysis make sure the appropriate preparation has taken place. A good rule of thumb is to review the following parts of the FEA.

- Confirm that instruction is an appropriate, cost-effective solution to the identified problem. In the majority of cases, instruction alone will not solve an organizational problem. For example, instruction may not address motivational or organizational issues. This may require not only design and development of education and training but also design and development of

organizational development programs. In our case, we will address issues and concerns that deal with the training portion of Six Sigma diffusion in the organization.

- Review data gathered from all sources about the nature of the problem. This includes contributing factors, causes, and solutions. You'll use this information when developing objectives and content, choosing delivery methods, and measuring whether or not learning has occurred. (Keep in mind that the requirements for executives, champion, MBBs, BBs and GBs are not the same; they must be treated differently.)

STEPS IN TASK ANALYSIS

Traditionally, the steps for conducting any task analysis have been to: 1) analyze your audience, 2) collect task data, 3) develop instructional objectives, 4) classify objectives by storage medium, and 5) develop assessment instruments. The same steps are applicable in Six Sigma methodology.

1) Analyze your audience: analyzing your audience gives you the information you need to tailor an instructional program to a particular audience. A major goal of creating any instructional program is to make sure the audience can understand, accept, and feel comfortable with the learning experience. For example, things like reading level, previous experience, and skill and knowledge level will impact an audience's reactions and degree of learning. You can control for this by becoming as familiar as possible with your audience and planning accordingly.

   If you know your audience, you can provide content, materials, examples, and instructional experiences with which your audience can closely identify. You can also use audience information to set design standards and baseline program requirements. For example, if the majority of your audience is at a ninth grade reading level, you can design your program and set entrance requirements to that level. Thereafter, those who are not up to a ninth grade level would need a prerequisite class. Those beyond a ninth grade level might need to take a higher-level course. On the other hand, if you expect all your participants to be graduate engineers or statisticians, the requirements would clearly change drastically, not only in the prerequisites domain but also in the instructional characterization of the material.

   Gather audience information from personnel records, surveys, etc. (This is very important in the case of figuring out the content of the overview and Green Belt training.) Focus on group, rather than individual characteristics, maintaining privacy of individuals. Pay particular attention to these characteristics:

   - Demographics: age, gender, culture (such as ethnicity and socioeconomic background), homogeneity of group
   - Capacity: intellect, physical development

- Competence: prior skills and training, experiential background, reading ability, languages spoken, current skill and knowledge level (relative to the instruction program), level within the organization
- Attitudes: values (toward training, subject), self-concept (academic, personal, professional)
- Motivation (goals, interests, perseverance)

Gather all task analysis information on two audiences: primary and secondary. The primary audience consists of those going through the instruction or using the job aid. The secondary audience includes anyone whose support is necessary for successful performance by the primary audience. (This is also significant because the results of this analysis should dictate, among other requirements, who is going to be trained as a Black Belt or a Green Belt.)

Support from the secondary audience (Green Belts, in this case) is vital to achieving transfer of learning and organizational results (e.g., productivity). The best-designed instruction or job aids alone will not guarantee transfer or changes in the bottom line. However, these things can be enhanced through secondary audience support. Generally, the secondary audience requires some instruction about what the primary audience has learned. They need to understand the value and benefits of the instruction — both to the primary and secondary audiences. This is why it is strongly recommended that the cascading training to the Green Belts should be done by the Black Belts.

The support or secondary audience usually includes the employees' supervisors as well as anyone whose work is related to or influenced by the primary audience performance. For example, if supervisors are being trained to manage in a more participative manner, their employees must be equipped to take on more responsible roles. In the case of Six Sigma methodology, for example, it would be ludicrous to assign a DOE responsibility to an operator if the operator has no idea of what DOE is or what to do.

2) Collect Task Data: two important benefits arise from collecting task data:
   - All the tasks required to perform expertly a particular skill, job, or function are identified
   - A sequence of instruction is determined

   A task is a series of *sequenced* actions leading to a desired outcome. Outcomes include broad instructional goals like giving a presentation, building a car, or changing a tire. Within ISD, outcomes are referred to as *terminal objectives.* Terminal objectives come directly from the front end analysis. Essentially, terminal objectives are the desired behaviors needed to solve the problem. The question you need to address is, What does an individual need to do in order to reach the desired outcome? (For example, what does an individual need to do to successfully change a tire? Or what does the Black Belt need to know to approach a project, solve it, and present the results to management?)

To answer these types of questions you need to locate all the tasks leading to your desired outcome — or to one broad, terminal objective (i.e., changing a tire, necessary knowledge of a Black Belt). Tasks include major tasks, which are refined and broken into subtasks, subsubtasks, etc. In the example of changing a tire, the following hierarchy may be developed with major, subtasks, and subsubtasks in a sequence.

- Terminal objective: change tire
- Major task: secure car
- Subtasks: set transmission; set parking brake; block wheel
- Subsubtasks: is the car automatic? If yes, put in park then move to subtask of setting the transmission; if transmission is manual, then put it in gear (first gear) and proceed to setting transmission in the subtask.

Once you locate *and sequence* all these tasks, this information can be used to create your instruction. Where do you go for task data? Sources for collecting task data vary. Use workplace sources *and* processes such as these:

- Interviews with accomplished performers, subject matter experts, etc.
- Administrative checklists and flowcharts
- Locally-constructed job aids
- Manufacturer suggestions and documents
- Observation of tasks being performed
- Process sheets
- Quality deployment sheets
- Research literature (periodicals, etc.)
- Surveys
- Tests
- Facilitating or focus groups using brainstorming, Delphi method, nominal method, etc.
- Critical incident reports

When collecting task data, consider using Table 2.5 as a guide. If you gather all this information on each task step, you will end up with a thorough knowledge base about each task. You will use this information to specify conditions and standards for your instructional objectives (discussed shortly). In addition, this information will become invaluable during later ISD stages (i.e., design and development). Remember, you need to use "variety" when collecting task data. This means gathering information from as many different sources and processes as possible. This will help minimize the risks associated with misinterpretations or individual biases.

3) *Develop instructional objectives*: task data tells you what an individual needs to do to reach a particular goal or outcome. Now you need to think in terms of what instruction is needed and how to help the learner reach the desired goal. Instructional objectives translate task data into required learner behavior. They are vital to the design and development phases. Without instructional objectives, you will not know what specifics to put into your instruction.

TABLE 2.5
Information about essential tasks

Find out about	Ask these questions
PREREQUISITE SKILLS AND KNOWLEDGE	What previously learned skills and knowledge must be present in order for the learner to understand the instruction?
TASK IMPORTANCE	How critical is the task to operations? What happens if task is not performed?
INITIATION	When is the task performed? What is the trigger event? Look for cues, signals, indications for action or reaction.
CONCLUSION	What is the concluding step or event in the task performance?
SUCCESSFUL COMPLETION	How is successful completion defined? Look for cues, signals, and indications that action taken is correct and adequate.
CONSEQUENCES OF UNSUCCESSFUL COMPLETION	What will happen if improper performance occurs? Are the potential effects expensive or harmful to operations?
FOLLOW-UP TASKS	Are there related tasks that need to be performed after this particular task step?
OTHERS INVOLVED	Are other task performers involved? Is a team effort required? Who is the leader?
TOOLS, EQUIPMENT, SUPPLIES, ETC.	What tools or commodities are used or manipulated for successful performance?
SAFETY CONSIDERATIONS	Does the task pose any risks to life, limb, equipment, or supplies?
REFERENCE MATERIAL	Is reference material needed during task performance?

Develop an instructional objective for each terminal objective, major task step, subtask step (if needed), and so on. Each instructional objective has three components (Mager, 1984; 1984a):

- The desired, observable task to be performed
- The standards by which the task accomplishment will be measured or evaluated for successful achievement
- The conditions or circumstances under which the task is performed

For example, an instructional objective for loosening wheel nuts when changing a tire is shown below:

- **TASK:** the user shall loosen the wheel nuts and raise the flat tire above the ground,
- **STANDARDS**: in ten minutes, without assistance, using appropriate safety procedures, without personal injury or damage to the vehicle,
- **CONDITION:** given a vehicle with a flat tire, jack and handle, wheel lug nut wrench, gloves, block, and operator's manual, under any road conditions.

Do you see how this information would help in making your instruction specific? You set the stage for the best way of learning or teaching a specific task. How you write your instructional objectives depends on the type of behavior you want the learner to demonstrate. For example, three