Implementation of Statistical Methods in Industry

B. Abraham
University of Waterloo

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Bovas Abraham
IIQP, University of Waterloo
Waterloo, Ontario, CANADA

Abstract

Statisticians have devised many tools to collect and analyse data from experimental and observational studies. However, attempts to bridge the gap between the available tools and what are praticed in industry have been very limited. It is very important for statisticians to direct serious attention to this issue if Statistics is to be relevant in the society at large. In this paper we propose some ideas for implementation of Statistical Methods based on our interaction with industry.

1. Introduction

What do we mean by implementation? An industrial organization is instituting Statistical Thinking and implementing statistical tools so that it becomes a part of the every day business. We are not thinking about a statistician consulting with a scientist or an engineer for a one time project even though such activities are important in their own right. Implementation, in the sense used here, is much broader and the associated issues are not trivial.

2. Levels of Statistical Need in Industry

We envision Statistics to play important roles at three levels of an organization: Strategic Level, Managerial Level and Operational Level. This classification is general and somewhat arbitrary. However, this identifies and emphasizes different tools to be directed at different levels.

(i) Strategic Level (Top of an Organization)

At this level the most emphasis should be on Statistical Thinking (ST) which includes the following: Notion of Process, Measurement and Data Based Decisions, Understanding and Dealing with Variation, and Systematic Approach. Decisions at the strategic level requires an understanding of variation and these decisions should be based on facts supported by data (Deming (1986)). Absence of these are quite prevalent in many organizations. Embracing any program that comes along is an expression of decisions not supported by data.

(ii) Managerial Level (Middle)

This is the level at which systems are devised for implementation of the directions taken by upper management. In particular, systems for process control and improvement, robust product

and process design, and training are the responsibility of middle management. Understanding of Statistical Thinking and some statistical tools are required.

(iii) Operational Level

This is the stage at which the methods are implemented through the system built at the managerial level. Understanding of statistical tools such as Control Charting, Capability, Design of Experiments (DOE), Measurement System Analysis, Regression Analysis, etc. and the actual use of these tools must be one of the objectives. Here people in different areas may not need the details of all the tools. For instance, an operator who is using a control chart for maintaining stability of a process need not know a lot about Design of Experiments; on the other hand an engineer responsible for process improvement should be knowledgeable in several aspects of Statistical Process Control (SPC) and DOE.

3. Implementation: General Issues

Commitment of Management

For the success of any program affecting the whole organization the full commitment of senior management is essential. They have to assess the situation early and decide to allocate the resources needed. If it is really important for the organization then senior people need to be involved in the implementation as well. Decide in advance what role they can and will play. For example, the success of the Six Sigma program at GE corporation is due to the commitment of its chief executive officer.

Expected benefits

It is important to recognize the benefits of implementation in the beginning. This helps to focus on what is needed. Of course it can help solve problems, improve processes and increase customer satisfaction. Another benefit is that a good measurement of performance can be done. An overall benefit is that it helps the organization to be a learning organization; a knowledge based company is going to be successful in the long run.

Systems Thinking

As in any other implementation, there are several components involved and these need to be considered as part of the system for implementation. Some of these components are: Statisticians, Other People, Technology, Methodology, Organizational Structure and Culture. These components have to work jointly so that the system yields improvements. We need to recognize that there will be 'effects' of each component and 'interaction effects' among the components. We have to build the system such that interaction effects are positive and that the total effect is more than the effects of the components. For example if there are two components A and B then $EF(A+B) \neq EF(A)+EF(B)$, but $EF(A+B)= EF(A)+EF(B)+EF(AB)$ where EF(A) stands for the effect of A. It is important to make the interaction AB (i.e., EF(AB)) positive so that the effect of A and B is more than the sum of the individual effects of A and B. Some

guiding principles such as Deming's 14 points for management can be extremely beneficial during the implementation. Such principles help to foster positive interaction between components such as people and technology. Often sophisticated software is used to train without considering the background of the trainees. This can lead to negative interaction.

Implementation of Statistical Methods can be part of other system implementations such as those of the quality systems ISO 9000, QS-9000, and Six Sigma.

Implementation Plan

We need to answer a number of questions before the activities can start. How does it start? When do the activities take place? Who is responsible for the tasks? What is the scope of the system, calendar of activities? What are the review points, and the associated expected results? Are resources assigned for the planned activities?

Project Implementation Systems:

There are many implementation systems that one can use. Deming's PDSA circle (Shehart's wheel) - Plan, Do, Study, Act (Deming (1986)) is a well known example. A similar system is used in a Statistics Course (Statistics 231) at the University of Waterloo - Problem, Plan, Data, Analysis, Conclusion (PPDAC for short). The Institute for Improvement in Quality and Productivity (IIQP) uses a 7-step system- Problem, Plan, Data, Solution, Confirmation, Standardization, Follow-up. There are many others used by various organizations.

4. Implementation via Training and/or Consulting

All organizations do have existing knowledge and acquiring new knowledge may require changes in thinking and culture of the organization. However, there has to be sensitivity about this issue and an understanding of existing knowledge base before anything is implemented. Also any plans for training should reflect this understanding.

Introduction of new knowledge requires training and the training needs for the different levels of the organization can be very diverse. This distinctive needs should be recognized and training programs should be designed in such a way to suit each of the Strategic, Managerial, and Operational levels.

Training Considerations

Trainers should have a thorough statistical background and good industrial experience. They should be aware of the culture and structure of the organization. Also they should have an understanding of the context in which they are working (for instance, interfacing with other Quality System trainings) and the background of the trainees.

The quality of the material presented is very important as it should be relevant to the particular needs of the trainees. Schedule and duration of each module is also important. In addition, presentation of the material in an understandable and enjoyable way requires careful planning. Material needs to be presented with implementable and understandable technology. Communication between the trainer and trainee and that between software and participants should be smooth. The interaction between people and technology should be positive.

Training programmes can be interfaced with other programs such as ISO 9000, QS-9000, and Six Sigma. In this case sequencing should be carefully planned and the interaction between the programmes need to be positive.

5. Implementation via Education

Today's students are tomorrow's employees. Industrial organizations need graduates with technical and nontechnical skills. These students have to get the education from the universities and it is difficult for the universities to provide all the skills needed to function in the workplace. However, a university statistics curriculum can be improved so that potential employees have enough statistics and communication skills. Many authors have discussed ideas for enhancing statistical education, see for example Garfield (1995), Hoerl et. al. (1993), Hogg and Hogg (1995), Snee (1993), Vere-Jones (1995) and Wild (1995).

Undergraduate Programme

A Statistics undergraduate program should include the following: Scientific method, Problem solving system, Measurement system analysis (MSA), Control charting, Design and analysis of experiments (DOE), Regression analysis, Sampling, Computing and Mathematics (see ASA (1980)). In addition, the students should get experience in solving industry related problems and communicate the results to people in other areas. There are different ways of achieving this goal. One method adopted at the University of Waterloo is to enrol the students in a co-operative program. In this system the students cycle between university and industry after each term during their undergraduate program. We will discuss this further later. Another approach may be to have joint programs between Engineering and Statistics; one can major in Statistics with a minor in Engineering or vice versa.

Graduate Programme

A useful model to consider is to require undergraduate engineering background for a graduate degree in Statistics or Engineering Statistics. Also one should design the graduate program to enable the students to have internships in industry. This can enhance familiarity with working environments, hands-on experience, and communication skills. Joint projects such as seminars between university and industry will also be very helpful. Seminars by people working in industry, not necessarily research seminars, but seminars with issues can open up project and thesis topics for students.

6. University - Industry Collaboration

Universities seek academic excellence. Industries require that their employees work on relevant issues. These two goals need not be on a collision course. With proper insight universities can provide academic excellence with relevance. Basically a university provides education to students. It can also provide faculty for training in the workplace. It is difficult for a university, by itself, to provide the well rounded education required for students to function in the workplace. Industry can help by providing contexts for relevance, and by their input into education. Collaboration between university and industry is essential to produce graduates for the future who can handle the difficult issues of the work place (Brajac and MacKay (1994), Hoadley and Kettenring (1990), Snee (1990)). Such collaboration requires carefully designed systems for implementation. Since this is not an isolated problem, this also should be thought in a systems framework.

In a university-industry partnership needs of University and Industry must be clearly defined, and roles of the partners clearly understood. The system should be flexible so that students and faculty can spend time in industry to enhance nontechnical skills and to gain some hands-on-experience. University courses can be modified to include project oriented teaching. The industry should provide opportunities to gain experience in problem formulation, planning of approach and data collection and problem solving. Different models can be used for undergraduate and graduate students. The collaboration system must make sure that the transition between university and industry is smooth for students as well as faculty. Also the systems should be flexible to accommodate student and faculty interests. It should also be important to recognize that long term commitments are required by both partners.

7. University of Waterloo and Industry

University of Waterloo has been involved with industry in several areas at different levels. Here we focus on the involvement related to Statistical Methods.

(i) Co-operative Programmes

The University of Waterloo has a large (probably the largest in the world) co-op programme involving about 10,000 undergraduate students annually. In this programme a student goes to an industry for a four month "work term" after every four month school term. Each student is expected to write a work term report for each work term, which will then be evaluated by the employer (industry) as well as by the University. Students are expected to finish 4-6 successful work terms during their degree programme. The Engineering Undergraduate programme at Waterloo is only available through the co-op option while other undergraduate programmes including Statistics are available by co-op as well as regular routes. Each "faculty" (college) has its own special requirements. However, all co-op placements in industry are administered through the Department of Co-Operative Education, a large administrative group on campus. In general, placement rates in Engineering and Mathematics are well over 90%. During recession periods, some difficulties in placing first year students were experienced, prompting some adjustments to the timing of work terms and academic terms.

There is a representative group from industry called the Waterloo Advisory Council which meets with University administration twice a year to exchange ideas on many issues facing the University and industry. Co-op education and University-industry collaboration is often discussed. This is an opportunity for the University to get input from industry regarding curriculum changes, new courses and programs.

(ii) Institute for Improvement in Quality and Productivity (IIQP)

University of Waterloo has many centres and institutes working with industry. Recognizing the prominent role of Statistical Methods in the QI activities the IIQP was established in 1985 as a liaison between the University and industry to implement Statistical Methods in industry. Its mission statement states:

> *"The Institute for Improvement in Quality and Productivity at the University of Waterloo is a group of individuals and corporate members committed to the development, communication and application of methods for quality and productivity improvement. The Institute's goal is to serve its members, the University and Business Communities."*

Goals and objectives of the Institute are:

- To provide a focus for multidisciplinary consulting and research in technical and managerial methods for improving quality
- To develop a centre offering courses and seminars for business and industry
- To aid in developing undergraduate and graduate programs in technical and managerial methods for quality improvement
- To facilitate experience-exchange programs between university faculty and industry personnel
- To stimulate development of innovative training methods in quality for the work place.

University members of the Institute include faculty members from approximately ten disciplines, and this enhances interaction among several disciplines which is helpful in carrying out technology transfer activities.

IIQP Activities - Training and Consulting

The IIQP has an active program of in-company and public courses spanning a range of topics in Industrial Statistics. To encourage rapid implementation of the methods taught in the classroom, work related projects are usually included as part of the courses. Third or fourth year undergraduate, Masters and PhD students have the opportunity of getting involved in these projects with industry, or serving as teaching assistants in the short courses that are offered.

Research

By promoting closer contact between faculty members and industry, the Institute encourages increased applied research on topics of great interest to business and industry. It plays a direct role in stimulating research in the University community through financial awards for graduate

work in areas relating to quality improvement. The Institute also provides direct financial support for faculty research. It publishes a research report series containing the results of current research done at the Institute. Graduate students have benefited from the funding provided but, more importantly, from the problems generated for their research from the industrial collaboration.

Co-op Students

The IIQP has been employing one or two undergraduate co-op students (Engineering and/or Statistics) each term. They routinely work with faculty members to help with projects. They have the opportunity of visiting companies initially with and later without faculty members.

Campus Course Curriculum Changes

Faculty members involved in the partnership gained valuable experience and ideas in working with industry. These have helped them to implement substantial changes to the content of Statistics courses at Waterloo.

The first course (second year undergraduate) taught to Mechanical and Systems Design Engineering students now centres around Continuous Process Improvement. These students are exposed to Experimental Design, Statistical Process Control, etc. and they have conducted experiments at industrial partner facilities during their work terms which have resulted in substantial annual savings. Significant changes have been made to a second year Statistics course in the Faculty of Mathematics. In this course, students conduct experiments in a laboratory in groups, deal with Measurement System issues and write laboratory reports as a team. Major changes have also been made to an advanced course in Experimental Design to reflect the applications in industrial partner facilities.

A wide variety of examples including casting, injection moulding, undercoating, etc. have been collected from partner facilities and these appear as examples in lectures and assignments. Students are excited by the fact that these examples are real and often involve thousands of dollars in savings (see Brajac and MacKay (1994)).

IIQP partnership with industry continues to provide many tangible and intangible benefits:

- Enhancements in content and delivery of courses
- Graduate and Undergraduate student involvement in real projects
- Enhancement of applied research of Faculty and Graduate students
- Professional development of the faculty members
- Enhancement of Statistical Thinking at some industrial partner facilities and modest cultural changes
- Application of newly developed methods in partner facilities
- Savings in real dollars for industrial partners

8. Concluding Remarks

Statistical Thinking and Methods need to become part of the knowledge base of an organization. We outlined many issues related to the implementation of Statistical Methods in Industrial Organizations. Implementation can be achieved by well planned and systematic training in the organizations and through the enhancements of university education by changes in course contents and delivery. We discussed the need for universities to form partnerships with industry to provide opportunities for students to enhance their skills. Some may argue that universities should be a place for education and should not be in the business of training. It is important to keep the balance, and all such endeavours should be motivated by "academic excellence with relevance".

It is important that the professional Statistician is equipped with good technical and non-technical skills. This is a challenge the universities have to face and one model for success is to form partnerships with industry as suggested. There is no need to compromise on academic excellence, however building in "relevance" to the programme enhances its value.

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