

Rini van Solingen
Egon Berghout

The
Goal/Question/Metric
Method

A Practical Guide for
Quality Improvement of
Software Development

MC
Graw
Hill

**The Goal/Question/Metric Method:
a practical guide for quality improvement of software
development**

**The Goal/Question/Metric Method:
a practical guide for quality improvement of software
development**

Rini van Solingen

and

Egon Berghout

THE MCGRAW-HILL COMPANIES

London · Chicago · New York · St Louis · San Francisco · Auckland
Bogotá · Caracas · Lisbon · Madrid · Mexico · Milan
Montreal · New Delhi · Panama · Paris · San Juan · São Paulo
Singapore · Sydney · Tokyo · Toronto

Published by
McGraw-Hill Publishing Company
SHOPPENHANGERS ROAD, MAIDENHEAD, BERKSHIRE, SL6 2QL, ENGLAND
Telephone +44 (0) 1628 502500
Fax: +44 (0) 1628 770224 Web site: <http://www.mcgraw-hill.co.uk>

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 007 709553 7

Library of Congress Cataloguing-in-Publication Data

The LOC data for this book has been applied for and may be obtained from the Library of Congress, Washington, D.C.

Further information on this and other McGraw-Hill titles is to be found at
<http://www.mcgraw-hill.co.uk>

Authors Website address: <http://www.mcgraw-hill.co.uk/vansolingen>

While having complete faith in the methods explained in this book when they are properly applied, neither the authors nor the publisher can accept any responsibility for the outcome of the application of these methods by users.

Publishing Director: Alfred Waller
Publisher: David Hatter
Typeset by: The Authors
Produced by: Steven Gardiner Ltd
Cover by: Hybert Design

Copyright © 1999 McGraw-Hill International (UK) Limited
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic or otherwise without the prior permission of McGraw-Hill International (UK) Limited.

1 2 3 4 5 CUP 3 2 1 0 9

Printed in Great Britain at the University Press, Cambridge

Table of contents

| | |
|---|-------------|
| ACKNOWLEDGEMENTS | xi |
| FOREWORD | xiii |
| 1 INTRODUCTION | 1 |
| 1.1 Objectives | 1 |
| 1.2 Organisational setting | 2 |
| 1.3 Schlumberger/Tokheim | 2 |
| 1.4 Origin of GQM | 3 |
| 1.5 Outline | 4 |
| PART 1: SOFTWARE QUALITY IMPROVEMENT AND GOAL-ORIENTED MEASUREMENT | |
| 2 SOFTWARE PROCESS IMPROVEMENT | 7 |
| 2.1 Introduction | 7 |
| 2.2 Improvement areas of software development | 7 |
| 2.2.1 Software products | 7 |
| 2.2.2 Software processes | 8 |
| 2.2.3 Software quality | 9 |
| 2.3 Software process improvement goals | 11 |
| 2.3.1 Increase quality | 12 |
| 2.3.2 Shorten project cycle time | 12 |
| 2.3.3 Decrease costs | 13 |
| 2.3.4 Decrease risks | 13 |
| 2.4 Approaches to software process improvement | 14 |
| 2.4.1 Assessment | 14 |
| 2.4.2 Measurement | 16 |
| 2.5 Conclusions | 16 |

| | | |
|------------|---|-----------|
| vi | THE GOAL/QUESTION/METRIC METHOD | |
| 2.6 | Questions and assignments | 17 |
| | 2.6.1 Questions | 17 |
| | 2.6.2 Assignments | 17 |
| 3 | GOAL-ORIENTED SOFTWARE MEASUREMENT | 19 |
| 3.1 | Introduction | 19 |
| 3.2 | What is software measurement? | 19 |
| 3.3 | Software metrics | 19 |
| 3.4 | Software measurement goals | 20 |
| 3.5 | Management commitment | 21 |
| 3.6 | Concepts of goal-oriented software measurement | 21 |
| | 3.6.1 The measurement concept: the GQM paradigm | 23 |
| | 3.6.2 The improvement concept: QIP | 25 |
| | 3.6.3 The organisational concept: experience factory | 26 |
| 3.7 | Questions and assignments | 28 |
| | 3.7.1 Questions | 28 |
| | 3.7.2 Assignments | 29 |
| 4 | COSTS AND BENEFITS OF GQM MEASUREMENT PROGRAMMES | 31 |
| 4.1 | Introduction | 31 |
| 4.2 | Cost of GQM measurement | 31 |
| | 4.2.1 Effort model for routine application of GQM | 32 |
| | 4.2.2 Effort model for initial introduction of GQM | 34 |
| 4.3 | Benefits of GQM measurement programmes | 36 |
| 4.4 | Questions and assignments | 37 |
| | 4.4.1 Questions | 37 |
| | 4.4.2 Assignments | 38 |
| | PART 2: THE GQM METHOD STEPWISE | |
| 5 | GQM PLANNING PHASE | 41 |
| 5.1 | Introduction | 41 |

| | | |
|------------|---|-----------|
| 5.2 | Planning procedures | 42 |
| 5.2.1 | Step 1: Establish GQM team | 42 |
| 5.2.2 | Step 2: Select improvement area | 43 |
| 5.2.3 | Step 3: Select application project and establish a project team | 44 |
| 5.2.4 | Step 4: Create project plan | 45 |
| 5.2.5 | Step 5: Training and promotion | 46 |
| 5.3 | Questions and assignments | 47 |
| 5.3.1 | Questions | 47 |
| 5.3.2 | Assignments | 47 |
| 6 | GQM DEFINITION PHASE | 49 |
| 6.1 | Introduction | 49 |
| 6.2 | Definition of procedures | 51 |
| 6.2.1 | Step 1: Define measurement goals | 51 |
| 6.2.2 | Step 2: Review or produce software process models | 52 |
| 6.2.3 | Step 3: Conduct GQM interviews | 53 |
| 6.2.4 | Step 4: Define questions and hypotheses | 55 |
| 6.2.5 | Step 5: Review questions and hypotheses | 56 |
| 6.2.6 | Step 6: Define metrics | 56 |
| 6.2.7 | Step 7: Check on metric consistency and completeness | 57 |
| 6.2.8 | Step 8: Produce a GQM plan | 57 |
| 6.2.9 | Step 9: Produce measurement plan | 58 |
| 6.2.10 | Step 10: Produce analysis plan | 58 |
| 6.2.11 | Step 11: Review plans | 59 |
| 6.3 | Modelling the software processes | 59 |
| 6.3.1 | Why model the development process? | 59 |
| 6.3.2 | The ETVX modelling technique | 60 |
| 6.3.3 | The ETXM modelling technique | 61 |
| 6.4 | Questions and assignments | 62 |
| 6.4.1 | Questions | 62 |
| 6.4.2 | Assignments | 63 |
| 7 | GQM DATA COLLECTION PHASE | 65 |
| 7.1 | Introduction | 65 |
| 7.2 | Data collection procedures | 66 |
| 7.2.1 | The need for data collection procedures | 66 |
| 7.2.2 | Manual forms of data collection | 66 |
| 7.2.3 | Electronic forms of data collection | 67 |
| 7.2.4 | Automated data collection tools | 68 |
| 7.2.5 | Restrictions to data collection tools | 68 |

| | | |
|----------------------|--|-----------|
| viii | THE GOAL/QUESTION/METRIC METHOD | |
| 7.3 | Data collection start up and training | 68 |
| 7.3.1 | Trial period | 69 |
| 7.3.2 | Kick-off session | 70 |
| 7.3.3 | Data collection activities | 70 |
| 7.4 | Building a measurement support system (MSS) | 70 |
| 7.4.1 | The need for an MSS | 71 |
| 7.4.2 | Development of an MSS | 71 |
| 7.5 | Questions and assignments | 74 |
| 7.5.1 | Questions | 74 |
| 7.5.2 | Assignments | 74 |
| 8 | GQM INTERPRETATION PHASE | 75 |
| 8.1 | Introduction | 75 |
| 8.2 | Preparation of a feedback session | 76 |
| 8.2.1 | Step 1: Update the analysis sheets of the MSS | 77 |
| 8.2.2 | Step 2: Create additional feedback material | 77 |
| 8.2.3 | Step 3: Update presentation slides | 77 |
| 8.2.4 | Step 4: Review presentation slides | 77 |
| 8.2.5 | Step 5: Save copies of slides and metrics base | 77 |
| 8.2.6 | Step 6: Create and distribute handouts | 78 |
| 8.3 | Holding a feedback session | 78 |
| 8.4 | Reporting interpretations of measurement results | 79 |
| 8.5 | Cost and benefits analysis of a measurement programme | 79 |
| 8.6 | Questions and assignments | 80 |
| 8.6.1 | Questions | 80 |
| 8.6.2 | Assignments | 81 |
| PART 3: CASES | | |
| 9 | CASE A: RELIABILITY MEASUREMENT | 85 |
| 9.1 | Description of project A | 85 |
| 9.2 | Planning | 85 |
| 9.3 | Definition | 86 |
| 9.4 | Data collection | 87 |

| | | |
|-------------|---|------------|
| 9.5 | Interpretation | 89 |
| 9.5.1 | Product overview | 91 |
| 9.5.2 | Overview on data collection | 92 |
| 9.5.3 | Q.6: What is the distribution of failures after delivery? | 92 |
| 9.5.4 | Q.7: What is the distribution of failures over severity classes? | 93 |
| 9.5.5 | Q.9: What is the distribution of faults after delivery? | 94 |
| 9.5.6 | Q.22: What was the relation between module reuse and reliability? | 94 |
| 9.5.7 | Q.12: What is the relation between module complexity and reliability? | 96 |
| 9.5.8 | Q.8: What is the distribution of failures over detection mechanism? | 98 |
| 9.5.9 | Types of severity by detection mechanism | 99 |
| 9.5.10 | Q.17: What is the distribution of failure handling effort? | 100 |
| 9.5.11 | Correlation of complexity versus size | 101 |
| 9.6 | Documentation of project A | 102 |
| 9.6.1 | Project A GQM plan | 102 |
| 9.6.2 | Project A feedback session report | 111 |
| 9.7 | Questions and assignments | 114 |
| 9.7.1 | Questions | 114 |
| 9.7.2 | Assignments | 114 |
| 10 | CASE B: REVIEW AND INSPECTION MEASUREMENT | 115 |
| 10.1 | Description of project B | 115 |
| 10.2 | Planning | 116 |
| 10.3 | Definition | 117 |
| 10.4 | Data collection | 119 |
| 10.4.1 | The RITME measurement support systems (MSS) | 119 |
| 10.5 | Interpretation | 120 |
| 10.5.1 | Fault finding capabilities of reviews | 124 |
| 10.5.2 | Learning capabilities of reviews | 130 |
| 10.6 | Documentation of RITME project | 131 |
| 10.6.1 | RITME GQM and measurement plan | 132 |
| 10.6.2 | Review form of the RITME project | 140 |
| 10.6.3 | Example feedback session report of the RITME project | 145 |
| 10.7 | Questions and assignments | 148 |
| 10.7.1 | Questions | 148 |
| 10.7.2 | Assignments | 149 |

| | | |
|-----------|--|------------|
| 11 | CASE C: INTERRUPT MEASUREMENT | 151 |
| 11.1 | Description of project C | 151 |
| 11.2 | Planning | 153 |
| 11.3 | Definition | 155 |
| 11.4 | Data collection | 157 |
| 11.5 | Interpretation | 158 |
| 11.6 | Documentation of interrupt measurement programme | 164 |
| | 11.6.1 GQM plan | 164 |
| | 11.6.2 Measurement plan of interrupts | 171 |
| | 11.6.3 Interrupt data collection form | 175 |
| 11.7 | Questions and assignments | 176 |
| | 11.7.1 Questions | 176 |
| | 11.7.2 Assignments | 176 |
| 12 | CASE D: EFFORT MEASUREMENT | 177 |
| 12.1 | Description of project D | 177 |
| 12.2 | Planning | 177 |
| 12.3 | Definition | 178 |
| 12.4 | Data collection | 179 |
| 12.5 | Interpretation | 182 |
| 12.6 | Documentation of SUPSYS measurement programme | 187 |
| | 12.6.1 GQM plan | 187 |
| | 12.6.2 Measurement plan | 189 |
| | 12.6.3 Data collection form | 190 |
| 12.7 | Questions and assignments | 192 |
| | 12.7.1 Questions | 192 |
| | 12.7.2 Assignments | 192 |
| | REFERENCES | 193 |
| | INDEX | 197 |

Acknowledgements

This book is based on many experiences we had in GQM measurement programmes. These experiences were gained in cooperation with so many other people. We like to emphasise that this book could not have been written without the help of all these people.

First of all, we want to thank the Schlumberger/Tokheim project teams that participated in the GQM measurement programmes. Their positive experiences and enthusiasm motivated us to continue the enhancement of the GQM method. It is not possible to include everyone personally, however, special thanks to Wim van der Bijl, Henry van den Boogaert, Erik Rodenbach, Erich Sigrist, Frank Simons, and Anita Verwegen.

The (inter) national research projects ESSI/CEMP, PROFES and SPIRITS certainly also contributed to the development of the GQM method presented in this book. Through the cooperation with all the organisations involved in these research projects, practical application of GQM was realised, evaluated and improved. Again, for these projects it is also impossible to name everyone involved, however, special thanks to Andreas Birk, Janne Järvinen, Rob Kusters, Frank van Latum, Markku Oivo, Dieter Rombach, Günther Ruhe, Jos Trienekens, and Erik van Veenendaal.

Several Master of Science students contributed to the research through supporting the application in practice and through adding many suggestions for improvements of the GQM method. Many thanks to Erik Kooiman, Hans Leliveld, Shyam Soerjoesing, Paul Stalenhoef, Arnim van Uijtrecht, and Cees de Zeeuw. A special thanks goes to Hans Leliveld for his contribution to an elementary version of this book. Marieke van Santen for her contributions to the web pages. Finally, we thank Rina Abbriata, Conny van Driel and Karin Nuijten for decoding our handwriting.

Rini van Solingen,
Eindhoven

Egon Berghout,
Rotterdam

The Netherlands
March, 1999

Foreword

The original ideas for the Goal Question Metric Paradigm came from the need to solve a practical problem back in the late 1970s. How do you decide what you need to measure in order to achieve your goals? We (Dr. David Weiss and I) faced the problem when trying to understand the types of changes (modifications and defects) being made to a set of flight dynamics projects at NASA Goddard Space Flight Center. Was there a pattern to the changes? If we understood them could we anticipate them and possibly improve the development processes to deal with them? At the same time, we were trying to use change data to evaluate the effects of applying the Software Cost Reduction methodology on the A-7 project requirements document at the Naval Research Laboratory.

Writing goals allowed us to focus on the important issues. Defining questions allowed us to make the goals more specific and suggested the metrics that were relevant to the goals. The resulting GQM lattice allowed us to see the full relationship between goals and metrics, determine what goals and metrics were missing or inconsistent, and provide a context for interpreting the data after it was collected. It permitted us to maximize the set of goals for a particular data set and minimize the data required by recognizing where one metric could be substituted for another.

The process established the way we did measurement in the Software Engineering Laboratory at Goddard Space Flight Center, and has evolved over time, based upon use. Expansion involved the application to other areas of measurement (such as effort, schedule, process conformance), the development of the goal templates, the development of support processes, the formalization of the questions into models, and the embedding of measurement in an evolutionary feedback loop, the Quality Improvement Process and the Experience Factory Organization. Professor Dieter Rombach was a major contributor to this expansion.

The GQM paradigm represents a practical approach for bounding the measurement problem. It provides an organization with a great deal of flexibility, allowing it to focus its measurement program on its own particular needs and culture. It is based upon two basic assumptions (1) that a measurement program should not be 'metrics-based' but 'goal-based' and (2) that the definition of goals and measures need to be tailored to the individual organization. However, these assumptions make the process more difficult than just offering people a "collection of metrics" or a standard predefined set of goals and metrics. It requires that the organization make explicit its own goals and processes.

In this book, Rini van Solingen and Egon Berghout provide the reader with an excellent and comprehensive synthesis of the GQM concepts, packaged with the support necessary for building an effective measurement program. It provides more than the GQM, but describes it in the philosophy of the Quality Improvement Paradigm and the Experience Factory Organization. Based upon experience, they have organized the approach in a step-by-step set of procedures, offering experience-based heuristics that I recognize as effective. They have captured the best ideas and offer them in a straightforward manner. In reading this

book, I found myself constantly nodding in agreement, finding many ideas I had not articulated as well. They offer several examples that can be used as templates for those who wish to have a standard set of goals and metrics as an initial iteration.

If you work on a measurement program, you should keep this book with you as the definitive reference for ideas and procedures.

Professor Victor R. Basili
University of Maryland
and
Fraunhofer Center for Experimental Software Engineering, Maryland

*'Its not enough to do your best;
you must know what to do, and then do your best'*
W. Edwards Demming

1 Introduction

1.1 Objectives

In the past few years we gained many experiences of organising software quality improvement programmes in industry. Although there are many textbooks available on quality improvement, we were surprised by the gap between theory and practice. Most literature on software quality is quite comprehensive, however, it often lacks the goal-driven nature of business. Business is not just looking for ultimate quality, but for the best quality to be given to other goals, such as timeliness, product features, complexity, or cost.

The Goal/Question/Metric method (GQM) supports such a business driven quality improvement approach very well, however, this method is merely published in scientific journals. This motivated us to write a practical GQM guide. We hope this book will inspire you during your quality improvement work in practice, and sincerely hope the practical material in this book prevents you making some of the mistakes we did.

This book has been written to support people that are working on quality improvement in the area of software development. It will focus on GQM and will provide:

- motives to start goal-oriented measurement;
- detailed steps to take for GQM application;
- examples of possible support for GQM;
- our lessons learned to prevent others making the same mistakes;
- templates of the necessary deliverables for GQM application;
- results from practice regarding goals we actually pursued and attained;
- suggestions for feedback material in which data is presented from projects we worked on.

This book is intended for:

- project managers setting up measurements towards a project or product goal;
- quality assurance personnel aligning the quality measures with the goals of their company and business;
- software engineers that want to structure their personal metrics;
- consultants that support companies in their process improvement and measurement programmes;
- teachers that want to explain to their students how to practically apply software measurement;
- last but not least, any other people interested in working actively towards a certain measurable objective.

1.2 Organisational setting

Our experience with GQM application has been developed in cooperation with many other companies and people mainly by participating in (inter)national projects. Three important projects are described below together with links to detailed information.

ESSI/CEMP: Customised establishment of measurement programmes.

The ESSI/CEMP project aimed at evaluation of the GQM-approach in the industry. The ESSI/CEMP project consisted of three practical case studies that investigated the introduction of GQM-based measurement in industry. The goals of the ESSI/CEMP project were:

- to provide cost/benefit data from three industrial case studies performed within ESSI/CEMP;
- to develop a set of guidelines and heuristics for the introduction of GQM-based measurement.

The ESSI/CEMP internet home-page contains free publications and deliverables of the ESSI/CEMP project: <http://www.iese.fhg.de/Services/Projects/Public-Projects/Cemp.html>.

PROFES: Product focused improvement of embedded software processes.

The PROFES project particularly focuses at organisations developing embedded software systems, in sectors such as telecommunications, medical systems, retailing systems and avionics. The PROFES methodology provides support to an integrated use of process assessment, product and process modelling, GQM measurement and experience factory. More information can be found on: <http://www.ele.vtt.fi/profes/>.

SPIRITS: Software process improvement in embedded IT environments.

SPIRITS was a research project of Schlumberger Retail Petroleum Systems (RPS) which was executed in cooperation with the Eindhoven University of Technology, The Netherlands. SPIRITS developed concepts and methods for process improvement to accomplish high and quantifiable reliability of embedded products. The main objectives were the design of:

- methods for process improvement in embedded systems development;
- methods for measurement and evaluation of the effectiveness of process improvement activities on the reliability of embedded products.

The practical application of the concepts and methods was validated in several case studies within Schlumberger RPS. The set of instruments was based on practical experiences and validated by a number of pilot projects.

1.3 Schlumberger/Tokheim

Schlumberger Retail Petroleum Systems (RPS) has been working for many years on developing and producing high quality products for petrol stations. As with most electronic products, the amount and importance of the software included in products is getting more and more important. Because of this trend, Schlumberger RPS extensively worked with

software quality initiatives to manage the quality of their software. This book provides an overview of the experiences gained during these initiatives. It was written, because particularly in the area of GQM, there was little documentation available. This book is intended as a guide for GQM application in practice.

This book is based on many quality initiatives within Schlumberger RPS over the past few years, such as:

- ISO9001 certification;
- TickIT certification;
- CMM assessments;
- Goal-oriented measurement by the GQM paradigm.

Initially, Schlumberger RPS worked with software measurement based on ISO procedures and CMM. However, this way of working was considered unsatisfactory. Not all collected data were actually used and other data were missing. In other words, the measurement programme lacked a clear goal and was experienced as being inefficient itself (Latum et al, 1998).

This observation led to the conclusion that software metrics should be defined in such a way that the collected data is relevant, and that it helps in achieving goals of business quality, such as product reliability which is not an isolated business goal. Because of this observation, the Goal/Question/Metrics paradigm was adopted to structure the measurements. During the several years of GQM application it appeared that there was little or no documentation on 'how' these measurement programmes should actually be carried out. At many events we met people from several industries or academics who all supported the power of the GQM paradigm, but none of them could point us to practical procedures, templates, or detailed examples from practice. Based on this notion we decided to capture our expertise in GQM application and write it down in this book.

September 1998, the RPS division of Schlumberger was sold to Tokheim, a company dedicated to fuel dispenser production. This sale created the largest system and service supplier in the retail petroleum market. Currently, Tokheim employs 5,000 people world wide, and has a yearly revenue of almost 1 billion US dollars.

1.4 Origin of GQM

The GQM method was originally developed by V. Basili and D. Weiss, and expanded with many other concepts by D. Rombach. GQM is a result of many years of practical experience and academic research. With this book we aim at contributing to their original work. Our contribution is the detailed analysis of the method and the addition of several techniques. An example of such an addition is cost/benefit analysis. Also included are many practical examples and suggestions to realise successful measurement programmes.