Executive Summary of MQP Assessment Activity in the Department of Biomedical Engineering for the Academic Year 2002-03

Prepared by Karl Helmer, January 2004

This material covers the MQP assessment for the Biomedical Engineering (BME) Department for the 2003 – 2004 academic year. Five documents are included: 1) an Executive Summary of all activities, 2) the "Departmental Requirements for the MQP" document that is distributed to all students and Program Advisors, 3) the revised Major Qualifying Project (MQP) tutorial that is available for all BME MQP groups, 4) the MQP Review for the 2003 – 04 projects, and 5) a summary of MQP-related items that were discussed during BME faculty meetings.

The Departmental Requirements document was drafted to codify the expectations of the Department, both for the report and the oral presentation of the project results. In the BME department, the MQP is used to satisfy the Capstone Design requirement. Therefore, in order to ensure that all of our students meet this requirement, we have structured the report format to emphasize the design process. To address the possibility of a disagreement on the Capstone Design designation between the project advisor and the reviewer, the students are now required to record the design process in a notebook that is returned to the department upon the project's completion. This can be used as further documentation of the project's design component. Because some BME students perform their MQP in departments other than BME, we have included associated Program faculty in the discussion of the MQP requirements. The additional requirements of advisors outside the BME department are dealt with on a case-by-case basis.

This was the fourth year that the MQP report tutorial has been available to the students. This document gives guidelines for formatting the report and gives the students information about what each section is expected to contain. It also gives students some guidance as to the actual writing of the report. This tutorial was revised again in response to the previous year's results of the review and comments by students and faculty. Along with the tutorial, the students are also given the evaluation sheet that will be used by the reviewer.

The review of MQP's for the 2003 – 04 academic year was performed over the summer of 2003. The results of this review were summarized in a report that was then distributed to the faculty. In addition, the reviewer also summarized the results during a faculty meeting and discussion was held on issues of concern that were raised during the review. This report also compiled statistics on the groups and the scores of the evaluation points.

MQP-related issues were discussed at BME departmental faculty meetings. Minutes of these meetings are compiled and are available for the ABET reviewer. These minutes have been summarized and are available as a separate document.

Requirements for a Major Qualifying Project in the Biomedical Engineering Department

The BME department has established requirements for the Major Qualifying Project (MQP) that must be fulfilled by each BME student. Because the MQP is used to fulfill the design requirement for ABET accreditation, these requirements must be met irrespective of the advisor's departmental affiliation or the number of BME students on the project. In addition to any special requirements made by the advisor, groups must 1) keep a design notebook that documents the design process, 2) complete an MQP report, and 3) present orally the results of the project.

Because of the importance of the design component of the MQP, each group is required to keep a notebook that documents the design history of the project and any other relevant documentation material. These notebooks will be available from the departmental office and will become the property of the BME Department upon completion of the project.

The MQP report must be written in a format that conforms to that given in the BME department's MQP Tutorial document. This tutorial is included as part of the BME department's MQP Resource Information Packet. The Packet can be found on the web at http://www.wpi.edu/Academics/Depts/BioMedEng/Resources/mqp_rip.pdf and contains both the tutorial and the forms that the departmental reviewer uses to evaluate the MQP reports.

The requirement that students present the results of their project orally can be fulfilled in a number of ways. The first is an oral presentation at the BME department's Project Presentation Day. This event is held in D-term of each year and involves both undergraduate and graduate presenters. All projects advised by BME faculty are required to present at this event. If your project is co-advised by a faculty member from a non-BME department, you may also be asked to present at their department's Project Presentation Day event. If your advisors are all from a non-BME department, the presentation requirement may be satisfied by presentation in that department's Project Presentation Day event. You are, however, also encouraged to present at the BME department's event, if possible. The presentation requirement may also be satisfied by a poster presentation in a non-BME department. For example, if your advisor is from the ME department, you may be asked to present in their Project Presentation Day poster session. If you will be presenting solely in a department other than BME, you must alert the BME department office to this fact prior to Project Presentation Day.

Review of Major Qualifying Projects

For the Academic Year 2002-2003

Department of
Biomedical Engineering
Worcester Polytechnic Institute

Submitted: October 28, 2003

Prepared by

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Table of Contents

1. General

a. Introduction

This document summarizes the review of the eight Major Qualifying Project (MQP) reports submitted in the 2002 - 2003 academic year. The reports for all teams that included a BE student were reviewed, irrespective of the advisor's department. The goal was to provide feedback to the advisor and to ensure that all projects met departmental criteria.

This was the fourth year that the MQP report tutorial was available to the students. This document gives guidelines for formatting the report and gives the students information about what each section is expected to contain. This tutorial was revised again in the last year in response to the previous year's results of the review and comments by students.

The MQP's reviewed this year were performed and written by teams ranging from one to four students. Twenty-five percent of the student teams (2/8) were multidisciplinary, meaning that at least one of the team members majored in a department other than BE. Two projects were advised solely by faculty outside of the BE department, while three others had a co-advisor from outside of the BE department. This means that 63% (5/8) of the projects were multidisciplinary with respect to advising.

Major Qualifying Projects are evaluated in three ways: 1) by grades given by the advisor(s), 2) by the evaluation of the MQP report by an independent reviewer and 3) by the evaluation of the presentation made at the Project Presentation Day. This report deals only with the second evaluation. The report evaluation form was revised again by the reviewer before this round of evaluation and will be revised again following the conclusion of this process.

b. Student Majors

There were a total of eight projects authored by 21 students. Their distribution by major is shown in Table 1.

Table 1. Number of Students Per Major

Major	Number
BE	19
ME	1
BBT	1

Twenty-five (2/8) percent of the MQP's were performed by multidisciplinary student teams (at least one student member was from a Department other than BE). This number is slightly higher than last year (2/9). This does not include teams in which all members were BE majors, but who had different concentrations. Of the 75% (6/8) teams that consisted of all BE majors, two projects were advised solely by faculty from a department (ME) other than BE.

c. Faculty Advising Loads

The average number of projects advised per faculty member was 1.3 (this is based on the six tenure-track faculty members). This is up slightly from 1.2 the previous year (based on five tenure-track faculty members). The highest was two and one faculty member did not advise projects. Three faculty members advised two projects, two advised one project. There were never more than two advisors on a project. Two projects were solely advised by a faculty members from another (ME) department.

d. Project Topics

Projects can be broken up into four broad areas: Biomechanical, Biomedical Instrumentation, Biomaterials, and Biomedical Imaging. The project breakdown into these categories is shown in Table 2.

Table 2. Major Topic Areas of MQP's

Major Topic Area	Number
Biomechanical	2 (25%)
Instrumentation	2 (25%)
Biomaterials	2 (25%)
Bioimaging	2 (25%)

2. Overview of Review Categories and General Comments

How To Use this Guide

The MQP review form (MQPRF) evaluates the results of the MQP in terms of the ABET criteria, but also evaluates the report writing, organization, and presentation. Each criterion is evaluated through multiple questions. The evaluation scale is 1 = Severely Deficient, 2 = Deficient, 3 = Adequate, 4 = Good and 5 = Excellent. As a rough guide, a "3" is given if the required material is present, but it is minimal. A "4" is given if the required material is there and it is well organized, comprehensible, and some thought appears to have been given to the contents. A "5" is given if the material is there, it is well organized and well thought out, and if the general level of the presentation is above the norm. (Note that for the Title Page and lists of Tables and Figures, "5" is the norm unless material is missing.) Means and standard deviations were calculated for each question using the data from all eight reports and the raw data can be found in the attached worksheet. The standard deviations can also be found in the attached worksheet.

The form used for the MQP reviews is also attached. On the worksheet, "nan" represents "not applicable", i.e., the question was not relevant to the project report. This designation was also given if the question was not applicable to the report. The designation "nf" stands for "not found" and a rating of "2" was assigned to that section if the material was either absent as a section, but some of the required material was dispersed throughout the text or the content was, indeed deficient. However, in section II where an entire section of the report was rated, if the section was not in the report it was given an “nf” rating.

Questions are referred to by designations that give major section, minor section, and question number. For example, “Ih1” means “section I, subsection h, question 1”. All questions were not appropriate for all MQP’s and therefore the means are calculated from different sample sizes. Some questions are exclusive. For example, if a project does not directly “address a contemporary biomedical issue” (Ih1) it may be “influenced by a contemporary biomedical issue” (Ih2).

The following is a discussion of the review criteria used for each section as well as some overall comments on the form itself. The results are tabulated and discussed in Section 2b-2h.

a. General

The goal of the current form is to gather information pertaining to the list of ABET categories. This form was designed to be useful for both science- and engineering-based projects and therefore not all sections are applicable for each project. The major difference between science projects and engineering projects is that in science projects, experiments are designed, conducted, and analyzed to investigate a hypothesis. In engineering-based projects, often a piece of equipment is designed and built to meet a specific need. Assuming that design of appropriate experiments constitutes a valid design experience, the reviewer found that all eight projects met the Capstone design requirements.

This is the fourth year using the standardized report format. This format was generally followed by all teams except for two that were supervised by one faculty member in the BE department. In those cases, significant deviations from the required format were found and this lowered the mean scores for a number of sections. One improvement was that the required format was followed for the two projects in which the main advisor was from another department. This is the result of discussions with faculty members in the ME department about the requirements for our students and our ABET effort.

Again, we reiterate that, the students should be encouraged to write out a list of specific aims for the project. Projects that did this were more focused and it was easier to review the merits of the report’s conclusions. This can be done for all projects, engineering and scientific alike. This list should be separate from the design matrix and should be as specific as possible. For example, “the voltage drift in our system should not exceed 5 mV/hr” rather than “the voltage provided by our system should be stable”.

In general, the ratings were positive, but the averages in some sections were reduced by two projects that did not follow the standard format and thus omitted crucial information. This year, on five questions the reports had an average rating less than 4 (where 1 = Severely Deficient, 2 = Deficient, 3 = Adequate, 4 = Good and 5 = Excellent). This is down from 11 last year (and 15 the year before that) and is another significant improvement. These areas are discussed below. Standard deviations for the means are given in the worksheet, but are not quoted in the text. Ratings of “nan” were not included in the calculation of the means. In section I, ratings of “2” were given to questions in which the answers were not present. If an entire section was not found an “nf” was given in the Section II ratings. This was done to help the reviewer flag whether the format was being followed for specific items.

b. Experiments on Living and Non-living Systems

This section is primarily used to rate the design portion of the project for scientific rather than engineering projects. However, if the constructed equipment was tested either to determine if the design criteria had been met or to actually use the equipment on the system of interest, this section was completed.

Question Ia1: The mean rating was 4.4, which means that the reviewer felt that the design goals were clearly defined for all projects.

Question Ia2: There were no projects that designed and implemented experiments on living systems this year. This is cause for some concern since this item is an important one for ABET.

Question Ia3: All projects this year involved experiments on non-living systems. The mean rating was 4.4.

Question Ia4: The mean rating for the extent to which simulations and tests were made in a structured manner was 4.1. This was down from 4.4 last year, but was not seen as a significant change given that the standard deviation was (4.1 ±) 0.6.

c. Analyze and Interpret Data

This section was used to rate those MQP’s that collected data in the course of the project.

Question Ib1: Again this year only three projects used any type of statistics in their report. The mean rating was 4.3.

Question Ib2: The mean rating for analysis of experimental data was 4.2.

Question Ib3: The rating for explaining unexpected outcomes was 4.0. This was an equal to that of last year. This year there were no deficient ratings and only 1/8 projects received an only an “adequate” rating.

Question Ib4: This was a chance for the authors to explain the limitations and applicability of their data. This was generally done in a satisfactory manner; however one project was deficient in this regard. The mean rating increased to 4.0 from last year’s mean of 3.2. This section was not included in one other report where it was deemed not necessary by the reviewer.

Question Ib5: This rated whether the conclusions were supported by the analysis. The mean rating was 4.0, showing that this section was well done for the majority of the MQP's. One report received an "adequate" rating and one report received a rating of "excellent"; the rest received "good" ratings.

d. Design Systems for Desired Needs

This section was used to rate the design component of the MQP - whether the design was of experiments or a piece of equipment.

Question Ic1: The rating of the clarity of presentation of the design goals was 4.4, a slight increase over last year's 4.2 rating. This question was identical to question Ia1 for most of the projects.

Question Ic2: This question rates the extent that the students synthesized in their design material from other sources. The material could be discussions with stakeholders as well as printed material and website material. The mean rating was 4.2, identical to last year.

Question Ic3: This question rates how well the team incorporated realistic constraints into the design, i.e., safety, cost, et cetera. Most of this was done through a "wants and needs" type of analysis using the specific aims. The mean rating for this was 4.6, a slight increase over last year's 4.4.

Question Ic4: This question rates the originality and creativity of the design. This is a difficult area to rate given that there is a rather stringent cost limit that the design must adhere to and this often limits the possibilities of the design. Most groups, however came up with workable if not inspired designs and hence the most common rating for this question was "good" (4/8). Two groups rated an "excellent", while two groups rated "adequate". The mean rating increased to 4.0 (last year = 3.6).

e. Multidisciplinary Team

Question Id1: A team was deemed "multidisciplinary" for the purposes of this question if: a) one of the students on the team was from a department other than BE, b) one of the advisors was from a department other than BE, or c) the team sought help outside the department in the form of consultants from other labs, departments or companies. Note that this is a different criterion than that of the student team itself being multidisciplinary. This year only one group was rated as not having some multidisciplinary component to it. The rating system was changed to a yes/no format this year as it was difficult to rate the degree to which groups were multidisciplinary.

f. Identify, Formulate, and Solve BME Problems

Question Ie1: This question rates to what degree the report conveyed that the group had interviewed the stakeholders in the project. Two groups did not explicitly mention such interviews and this reduced the mean rating down from 4.6 last year to 4.2. The importance of including this information should be emphasized by the advisor since this information usually drives the design.

Question Ie2: This question rates how well the students established clear objectives for the project. "Clearly stated" was taken to be of the form "here's the problem and here's what we want to do". This question is related to the project's specific aims and design goals, as the objective was often to design and build a device with a certain set of operating characteristics. Therefore, the ability to clearly state design goals (Question Ia1 and Ic1) and specific aims (II9) were related. However, because the Specific Aims were also rated as to content as well as their explicit statement, the Specific Aims were rated lower (see II9). The mean rating was for Question Ie2 was 4.2, down from 4.6 last year. This decrease was, in part, due to a single "deficient".

Question Ie3: This question rates whether or not (and how creatively) the students considered alternative solutions. This was somewhat difficult to rate, since simpler solutions are often the best and it can be that there are not many different cost-effective ways of achieving a goal in a limited amount of time. The mean rating was 4.2, an increase from last year's mean rating of 3.9. The importance of this section cannot be overestimated, since the presentation of the design evolution is not only important to future groups, but also helps in the appreciation of the final design.

Question Ie4: This question rates how well the proposed solution was tested. The mean rating was 4.3, indicating that most of the testing done was of sufficient quality (last year = 4.0). This is an important part of the design process since if no testing is done students have no way of gauging how well their design performed. This should continue to be stressed by the advisor.

Question Ie5: This question rates how well the end product correlated with the original specifications. The mean rating was 3.9 indicating that the outcomes of most projects satisfied the Specific Aims (last year 3.8). The mean rating was decreased by a single "deficient" and one "adequate".

g. Effective Communication

Question If1: This rates the clarity and logical organization of the report. The organization issue was basically irrelevant as most reports followed the prescribed format. The mean rating was 4.0. This was a slight decrease over last year (4.2).

Question If2: This question rates the grammar and style of the report. This had a mean rating of 4.0, an increase over last year (3.6). The main problem was that 2/8 reports were not edited very thoroughly and this reduced the mean.

Question If3: This question rates the student's ability to explain complex ideas. This rating for this area held relatively steady with a mean of 4.0 (last year = 3.9). The main problem was a reluctance to explain basic ideas in anything deeper than a cursory level.

Question If4: This question rates the appearance of the document. The mean was 4.4. This was an increase from last year (3.9). Better use of graphics was a major reason for the increase. As a side note, students should be aware that increasing the size of figures can result in the figures not being readable. Scanned figures should therefore use sufficient resolution to alleviate this problem. This should also be caught in the editing phase.

h. Global and Societal Impact of the MQP

Question Ig1: This question rated how clearly the students thought about the impact of their project on the users of the device, animals, or on the environment. This was applicable to 5/8 projects. The mean rating was 4.6 (last year = 4.5). These issues were usually raised in the course of the discussion on the design and its alternatives.

i. Contemporary Issues

Question Ih1: This rates how much the project addressed a contemporary biomedical problem. The mean rating was 5.0. This question was applicable for all nine projects.

Question Ih2: This rates how much the project was influenced by a contemporary biomedical problem. This question was used if the project was peripheral to a pressing issue, but did not directly address such an issue. This question was not applicable for any of the projects this year. It should be noted that the division of the projects into projects that "address" or "are influenced by" important contemporary issues is somewhat subjective.

j. Modern Engineering Tools

This question rated the extent to which students used state-of-the-art-engineering tools in the project. The question was worded to include design, analysis and presentation packages, which may be too broad. The mean was 4.5 (last year = 4.4), implying that most projects used state-of-the-art technology in the course of completion.

k. Professional and Ethical Responsibilities

Question Ij1: This question rates the extent to which the relevant ethical issues were identified and addressed. Again this year, this was not an issue for any of the projects. Related discussions were, however, evaluated in question Ig1 in which students looked at the potential effects of their project.

l. Life-long Learning

Question Ik1: This question rates the student's ability to assemble a relevant and complete list of references. This was well done in most cases. The mean rating was 4.0 (last year = 4.4). The decrease was due to a single "deficient" (no references other than a patent were cited) and two "adequate" ratings.

Question Ik2: This question rates the student's ability to synthesize material from a variety of sources. This question was connected to the student's ability to write a convincing literature review section. The mean rating was 3.9 down from 4.3 last year. Again, the issue was one group that did not have a literature review other than a reference to a patent and several groups had minimal sets of references that were based on webpages rather than published articles.

m. Quality of Each MQP Section

Sections were reviewed as a whole in this part of the review form. The review criteria covered how well the section material was presented, whether or not the section complete, whether or not the correct material was presented in that section and were standard scientific practices followed. The rating values for the previous year are given for reference. Standard deviations are given to help assess the significance of any changes.

Section	Mean rating (2003)	Mean rating (2002)	Mean rating (2001)
Title Page	5.0 ± 0.0	5.0 ± 0.0	4.8 ± 0.7
Table of Contents	5.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
Authorship Page	4.9 ± 0.4	4.7 ± 0.5	4.5 ± 0.5
Abstract	4.2 ± 0.7	3.4 ± 0.9	3.3 ± 0.7
Table of Figures	5.0 ± 0.0	4.9 ± 0.1	5.0 ± 0.0
Table of Tables	5.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
Introduction	4.6 ± 0.5	3.8 ± 0.4	3.9 ± 1.0
Literature Review	4.0 ± 0.6	4.1 ± 0.6	4.0 ± 0.0
Specific Aims	4 ± 1		
Project Approach	4.2 ± 0.7	4.0 ± 0.5	4.0 ± 0.8
Design	4 ± 1	4.2 ± 0.9	4.0 ± 0.8
Methods	4.2 ± 0.5	4.3 ± 0.5	4.3 ± 0.5
Results	4.4 ± 0.5	4.2 ± 0.7	4.3 ± 0.7
Analysis and Discussion	3.9 ± 0.8	3.9 ± 0.9	3.8 ± 1.0
Conclusions	4.0 ± 0.5	3.9 ± 0.9	3.4 ± 0.9
Recommendations	4.2 ± 0.5	4.0 ± 0.9	3.5 ± 0.9
References	4 ± 1	4.2 ± 0.7	4.4 ± 0.5
Glossary	5.0 (N=1)	4.0 ± 0.8	4.7 ± 0.6
Appendices	4 ± 1	4.1 ± 0.3	4.8 ± 0.5

The abstract is still an area of concern. The most common deficiency was the failure to include the relevant numbers (with their associated errors). Advisors should pay special attention to the student's abstract, make sure that it is in standard journal format, and make sure that it gives specific information about the project's results. In general, sections that required the students to have insight into their project results or to clearly explain their project's goals were rated lower than other sections. This is most likely due to their lack of experience in scientific analysis and writing. The areas of largest improvement this year was the Introduction section. This is a good sign, implying that more groups are able to see the "big picture" for their project.

n. Capstone Design

This last question asked whether or not the Capstone Design requirements had been met. Some of these questions have been now formulated as yes/no-type questions rather than being rated on a scale of one to five. All of the MQP's were found to meet the Capstone design requirement.

Question III1: This question asked whether or not there was an open-ended need for the project. The mean rating was 4.5 (last year = 4.8).

Question III2: This question asked how well the problem was defined and whether or not the design criteria were stated fully. The mean rating was 4.5 (last year = 4.7).

Question III3: This question asked whether or not alternative designs were created and reviewed. The mean rating was 4.0 (last year 4.1). There were one "deficient" and two "adequate" ratings. Students should include a design history in the Design chapter, otherwise the reviewer cannot tell if the design was handed to the group or if they struggled with the problem themselves.

Question III4: This question asked whether or not at least one design was analyzed. The mean rating was 4.2 (last year = 4.1).

Question III5: This question asked whether the final design was discussed or refined. The mean rating was 3.9, down from a rating of 4.2 last year. There were two "deficient" and one "adequate" ratings.

Question III6: This question asked whether the final design was fabricated. This was true for 6/8 projects (last year = 7/9 projects).

Question III7: This question asked whether the final design was tested. This was true for 6/8 projects (last year = 7/9 projects).

Question III8: This question asked whether the final design was sufficient to satisfy the Capstone requirement. This was true for 8/8 projects (last year = 8/9 projects).

3. Summary

This year's reports have shown improvements in some important areas and have held steady in others. The ratings for this year's reports were generally satisfactory in that most areas scored close to a "good" rating. "Good" denoted that the report met the criteria to the reviewer's satisfaction.

Another milestone for this year that faculty in the ME department who advise our students are now ensuring that the reports are in our format and meet our requirements.

Two groups seemed to have read the report tutorial, but did not apply the guidelines. Because the MQP is an important part of our assessment effort, it is imperative that advisors check the report before it is submitted to ensure that it meets departmental requirements. In addition, advisors should be conversant with the tutorial document since the tutorial cannot hope to cover every eventuality.

There are a number of common problems that I noticed in reviewing all of the MQP reports. They are:

1) The document was spell-checked, but not edited (this is becoming rare, but still happens in individual sections).

2) Recommendations seem to be coming from project stakeholders, but there is no indication or reference to any meetings with the stakeholders or who they are.

3) The Design chapter gave design criteria, but no indication of the design history.

4) Acronyms and uncommon words were not defined upon first usage.

5) Figures should be scanned at sufficient resolution so that they are legible when put into the document and rescaled.

This year the reviewer's comments are again becoming increasingly more about the technical aspects of the report format and production, rather than the technical aspects of the project. Therefore, advisors are asked to ensure that their groups understand the department's requirements and/or ask the MQP reviewer to meet with their group.

4. Feedback

This document will be presented to the BE faculty at a departmental meeting. The results and recommendations from this evaluation will be discussed among the entire faculty. Decisions made during these discussions will then be implemented in the following year's projects. In addition, the MQP tutorial, used as a guide by students to write their reports, will be revised again based on the comments of the faculty.

Following this year's review the current evaluation form will be revised. This revision will focus on tightening the wording on some questions to eliminate overlap. This revision will be performed at the conclusion of this review and the new form will be made part of the revised MQP report tutorial that will also be revised in light of some feedback that was obtained from the EBI survey and students comments on the document itself.

Worcester Polytechnic Institute

Department of Biomedical Engineering
Major Qualifying Project
Report Tutorial and Information Packet

Preface

This guide will help you to write your Major Qualifying Project (MQP) report. It explains the two types of biomedical engineering MQP's, how to tailor your report to the type of MQP you choose, and how to format your report. Using this guide will help you to approach your MQP problem while providing you with the means of documenting the entire process.

What is an MQP report?

The MQP report is a unique document whose purpose is to document completely your MQP from problem conception to final result. In addition, the report must communicate that you have mastered the material needed to complete the project.

Mastery, at this point, does not mean that you have to become an expert in the field, just that you understand and can communicate the basic concepts underlying your project. For example, if your project deals with the absorption of light by blood, can you explain how such absorption is measured? Can you explain the physics behind such absorption, i.e., what happens to the blood when it absorbs the light? Can you explain the results you obtained? You need to convince the reader that you understand where the problem fits into your field and what all the relevant issues are.

What is the format of an MQP report?

Your report will have two parts. The first is the Proposal, where the problem is identified and put into context using background material. The second is the Methods and Results, where you describe what you did, what the results were, and how you are interpreting them.

Part I – Proposal

The Proposal chapters introduce the reader to the problem that your project is trying to address. Therefore, these chapters should present background material that helps the reader to understand the context of your project aim. Usually, providing a context entails summarizing previous published research. This context may also be supplemented by summarizing preliminary work performed by previous MQP groups or their recommendations. The purpose of background material is to convince the reader that your ideas are sound and that the work you are proposing has a good chance of succeeding.

Part II – Methods and Results

This part gives the reader the details of what you did and what the results were. In addition, this part includes chapters that discuss the results (Analysis and Discussion chapter) and a big-picture summary of their significance (Conclusions chapter).

Although the second part of the MQP report resembles a journal article, it contains more information than is usually presented in such an article. This additional information shows the reader the steps you took along the way to your final result. For example, in your report you will have a chapter covering the design of your experiment or device. There you will need to describe your initial through final designs and what criteria you used to decide on specifications or changes. By contrast, professional journal articles report only final designs and results.

Audience

Before you begin your report you should have a clear idea of your intended audience, which will determine the level of detail present in the report and the amount of background material that is presented. In the case of the MQP report, you are writing for other students who may be continuing the project or people outside of the field who may know something of what you are doing, but who are not experts. Your document should therefore contain more background information than you would include normally in a journal article. (Note that including this background material helps to demonstrate mastery of the subject.)

Summary

In summary, the goal of your MQP report is to document thoroughly your MQP from problem conception to final result. You must convince the reader that you understand the history and relevance of the problem you are working on and why you chose to attack the problem in the manner that you did. The evolution of your design should be documented in a way such that the reader can follow your reasoning. The experimental methods that you used (whether for an experiment or for testing a device) should also be documented completely so that the reader can interpret the applicability and viability of your results. You should then state your final results and your interpretations of them. Finally, you should be able to make some recommendations for future work.

Contents of This Guide

This packet contains all the information necessary to complete your MQP report successfully. It is a good idea to look through this material before you start work on your project and to refer to it as your work progresses, so that you have a coherent and logical approach and that you follow the correct format. Enclosed you will find:

1. A document outlining the general format of an MQP report
2. A sample table of contents
3. A sample evaluation form used by the MQP report reviewer
4. A sample oral presentation evaluation form.

The general report format document briefly explains the purpose of each part of your report and what material should be included in that section or chapter. Each MQP report should include most if not all of this material (although the exact format of each section and chapter can vary and will depend upon the nature of the project). Before you begin to write your report consult your advisor(s) for more information specific to your MQP.

The sample table of contents covers all of the sections and chapters outlined in this document and where they should appear in your report. All of the sections and chapters in the sample are applicable to all projects.

Your MQP will be reviewed twice by people other than your advisor(s): first, during your formal oral project presentation on Project Presentation Day (before it is submitted for final grading), and second, after your report is finished and graded. Therefore, to allow you to see the evaluation criteria that faculty will be using, this packet includes both the report and oral presentation review forms.

Types of Projects

There are two broad types of MQP projects: scientific and engineering. Scientific projects involve the design and implementation of experiments conducted to answer a scientific question. Engineering projects usually involve the design and construction of a device for a specific purpose. For example, figuring out why tissue pH changes during ischemia would be a scientific project, whereas a project to design a more reliable tissue pH meter would be more properly classified as an engineering project. The type of project will determine both your approach to the project and the style and specific organization of the final report. Discussed below is how to adapt the initial chapters of your report to the type of project you are doing and a summary of the differences between science-and engineering-based MQP's.

For both types of projects, the initial step is to identify a problem to be solved. In a scientific study, the "problem" is usually a missing piece of knowledge. In other words, some observations have been made that cannot be explained with the current state of knowledge in the field. For example, it may not be known why tissue pH changes in response to a particular disease. However, in an engineering study, the "problem" is often that there is a need to be filled. For example, there may be a need for a noninvasive tissue pH-measuring device, because an early symptom of a particular disease results in a change in tissue pH.

The next step is to decide how to solve the problem. For a scientific project, you must develop a hypothesis, i.e., you must speculate on an explanation for the unexplained phenomenon. For example, your hypothesis might be that the tissue pH changes because a disease disrupts the production of ATP. Your scientific project would then seek to prove or disprove this hypothesis through experimentation.

Instead of Hypotheses, engineering projects have Project Objectives. In this case, an Objective might be to design and build a device that measures the change in pH over the disease progression.

You then need to state exactly what you intend to achieve during your MQP project. In a scientific project, this is detailed in your Specific Aims section. The Specific Aims should be tied directly into your hypotheses and it is common to have at least one Specific Aim for each hypothesis. For example, if your hypothesis is that the pH changes because ATP production is disrupted, one of your Specific Aims should be to measure the ATP production.

In an engineering project, this list of proposed achievements is called the Project Specifications. If your Objective is to measure the small pH change that occurs over the course of the disease progression, then a Project Specification of your project should be to construct a device with the required accuracy to measure that small change.

In general, the two methods can be summarized as follows:

Step	Scientific Project	Engineering Project
1	Make observations	Make observations
2	Identify missing knowledge	Identify a problem/need
3	Make hypotheses	Project Objective
4	Formulate Specific Aims	Project Specifications
5	Design experiments	Design device
6	Perform experiments	Build the device
7	Analyze the data	Test performance
8	Interpret the results	Decide on a final design
9	Lead to further questions	Identify areas needing improvement

The format given below is appropriate for both types of MQP's. Each section heading shown below should appear in your MQP report; however, the contents of the sections will vary from project to project. This document is designed to give as much guidance as possible, but a single document cannot cover all eventualities. You should, therefore, consult your advisor when questions arise.

Report Sections

TITLE PAGE

The Title Page should include the title of the project, the name(s) of the author(s), the date of final approval (month and year), and the name(s) of the project advisor(s). The Project Office requires that you list three keywords pertaining to the project on the left side of the page, opposite the advisors' signatures. Careful thought should be given to the selection of an appropriate project title. A sample Title Page is included at the end of this tutorial. Text that appears in <   > is specific to your project.

TABLE OF CONTENTS

A Table of Contents directs readers to the location of specific information and gives them a quick overview of the entire project. Use the decimal numbering system for both sections and subsections. Note that material that is not the actual text of your document is numbered using Roman numerals (for example, the Table of Figures). Pages of document text are numbered using Arabic numerals.

AUTHORSHIP PAGE

The Authorship Page should identify the work for which each group member was responsible. Information should be provided not only for the actual project work, but also for the writing of the report. This section should not exceed one page.

ACKNOWLEDGMENTS

In this section, it is customary to list each person and organization that has contributed to your work. The nature of the contribution (e.g. permission for the use of equipment, access to facilities, etc.) should be described.

ABSTRACT

The Abstract should present a concise overview of the project. The Abstract should clearly state the project's objectives, rationale, a brief summary of the procedure employed and the final results produced from the project. The Abstract should be written as a completely self-contained section, i.e., it should provide sufficient information for a general understanding of the project's goals and results.

Because the Abstract is necessarily brief, it can be difficult to write. Effective abstracts:

1) will contain enough specific information to satisfy the needs of a researcher looking for information and of an administrator looking for a progress or status definition;
2) will be a complete, self-sufficient description of the work and the results;
3) will contain numerical results and their associated errors, if appropriate (e.g. 10.1 ± 0.3 sec);
4) will be brief and contain only the results themselves and the conclusions, but no discussion of the results;
5) will be written for the general reader in easily understood language, but may contain standard, generally recognized abbreviations, and
6) will be consistent in tone and emphasis with the parent report or paper.

Using the list above, you can see that an abstract should be written after the project work is complete, the data analyzed, and the first draft of the report written. However, because the Abstract is written last, it often suffers from being done quickly. This is unfortunate since the Abstract is usually read first and a reader will often form a general impression of the work from the Abstract. Thus, careful thought and planning is required to insure that this section reflects the quality of the entire report. The typical length of an abstract is approximately one double-spaced page; however, WPI limits abstracts to 80 words.

TABLE OF FIGURES

Figures should be numbered using the "chapter.figure #" format e.g., the third figure in Chapter 5 is Fig. 5.3. Note that in referring to a particular figure in the text or caption, the word "figure" is always capitalized and abbreviated (i.e. "Fig."), except at the beginning of a sentence, where it is capitalized and spelled out. This table should be placed on a separate page.

TABLE OF TABLES

Tables should be numbered using the same format as that used for figures. However, the table number and table description should be placed at the top of the table. The word "table" is always written out, not abbreviated. In references to a specific table in the text, the word "table" is always capitalized. This table should be placed on a separate page.

Part I - Proposal

The Proposal is made up of the first four chapters of your report. (Note: the word "chapters" is used rather loosely here. As defined, some of your chapters may be only one or two pages long.) In the Proposal, the goal is to present background information necessary to the understanding of your project and to detail how you intend to solve the problem you have chosen. Note that, by necessity, you will use past and future verb tenses in this section. The background information you present describes work that has already been done. Therefore, that material should be written using the past tense, e.g., "Firefly, et al. (1964), **were** the first to realize that a change in tissue ph accompanied tissue ischemia." The work you intend to do, however, must be written in the future tense, e.g., "We **will find** a cure for pancreatic cancer." The use of the future tense indicates that you have not yet done the work, so this material should be written before you start your actual experiments or construction. Writing this material will help you synthesize the background reading you have done and ensure that you have a firm understanding of the problem and the necessary fundamentals.

CHAPTER 1—INTRODUCTION

The goal of this chapter is to provide an introduction to your project written in language that a general audience can understand. The introduction should, in the broadest terms, identify the problem and the project objectives. Remember that the background material has not yet been presented to the reader, so you should not assume that the reader has any special knowledge. This chapter should (briefly) address the following questions:

- What is the general problem you are addressing? For example, if your project is related to diabetes, you should give the reader a general impression of how prevalent diabetes is and some background of the disease. This is to give the reader some context with which to follow your literature review. This part should answer the question, "**why** are you doing the project?"
- What are the overall goals of your project? This should be written so that the reader has a clear grasp of the scope of your project. This part of the Introduction should answer the question, "**what** are you going to do?"
- What is the general procedure that will be employed in conducting the project? This material should answer the question, "**how** are you going to do it?"

The final paragraph/paragraphs of the Introduction should preview briefly the contents of each of the succeeding chapters. It is important that this material present an accurate description of what appears later in your MQP report and, therefore, should be one of the last chapters that you write. The Introduction will rarely exceed four or five pages.

CHAPTER 2—LITERATURE REVIEW

This chapter provides the intelligent but non-specialist reader all the introductory information needed to understand the general problem that your project addresses as well as your project's Specific Aims. Your literature review must give the reader a brief summary of what is currently known about your problem area. You should think of this chapter as your chance to build a logical argument that will convince the reader that your approach is reasonable and one that will produce relevant results.

The goal of this chapter is to build a logical argument that leads to your project approach and Specific Aims. This chapter should include the following:

1. Information about the importance of the field that you are working in
2. How your specific project relates to the larger problem area
3. A summary of what is currently known (and unknown) about the area your project addresses

4. A summary of the current mathematical models used in this field and their assumptions and/or:
5. A summary of the relevant devices now in use in this field.

After reading your literature review, your audience should be able to follow the technical reasoning you provide for your project design and your conclusions.

The literature review is important even for projects in which the goal is the design and construction of a device. The reader must understand the general problem so that the device specifications that you have chosen will be meaningful. In addition, if current devices are not fully discussed, the reader has no context against which to judge the success of your device.

The literature review elaborates upon details and topics that were treated in a cursory fashion in the Introduction chapter (e.g., the importance of the project, debates concerning aspects of the project, specifics on alternatives, benefits to be derived from the results of the project, etc.). It should discuss only work performed by others, but not the work you performed as part of this project.

This chapter is usually quite lengthy and extensively documented (footnotes may be placed together at the end of the chapter to facilitate typing). References are necessary for all quoted material, all specific facts that are not general knowledge, and all quantitative data. WPI has adopted Kate Turabian's *A Manual for Writers of Term Papers, Theses, and Dissertations* (based on the larger *The Chicago Manual of Style*) as the standard style guide for documentation. See the References section in this guide for more information on the format for references.

The literature review can be difficult to write if treated as a repository for all of the material that you read during the research phase of your project. If, however, you think of the literature review as a story you are telling readers to get them to your level of understanding, the literature review becomes much easier to write. Remember that when telling a story, you don't want to include everything you know about what happened. It is better to put only the relevant facts in the review, the facts that lead the reader directly to understanding your project approach. If approached in that manner, the background material is much easier (for you) to organize and for the reader to understand.

You should include a work in the literature review for any of the following reasons:

1. It provides a historical development of the subject. Remember that you are trying to provide the reader with the background information that will be needed to understand the choices made in the project and the interpretation of the results.
2. It points out limitations of previous work.
3. It provides supporting evidence (either data or theories) for your point of view.

4. It raises opposing viewpoints. You will have to address any data or theories that run counter to your hypotheses. Either they must be shown not to be applicable to your situation or countered with preliminary data that show them to be wrong.

The point is that you should cite work only when you have a reason – either to support what you are arguing or to ward off criticism of your work by showing how data or arguments that disagree with you are either flawed or inapplicable to your work. All material that you read during the research phase does not need to appear in the Literature Review.

When citing a work, remember that you are trying to tell the reader a story and that the work that you want to refer to should be woven into the narrative. Imply rather than state that a work is important. Instead of, "This work is important because…" tell the reader the work's main finding. For example, "Hackenbush, et al. (1964) found that the mean pO_2 of C3H murine tumors increased by 50% when the animals were breathing carbogen gas."

Though you should be concise, you should include enough detail so that the reader can understand the significance of the citation. Assumptions that were made and numerical results (with errors) should be reported if they are crucial to your argument. If you are critiquing a work, enough detail needs to be included so that the reader can fairly assess your criticisms.

CHAPTER 3—PROJECT APPROACH

For both types of projects (engineering and scientific), this chapter outlines your ideas about the solutions to your problem (your hypotheses or Project Objectives) and what you intend to do in your project (your Specific Aims or Project Specifications). A hypothesis is generally considered an educated guess, proposing a possible solution to the problem or question raised by your preliminary investigations and literature review. A Project Objective is a statement of what is needed to solve the problem presented by the client.

In a scientific project, a Specific Aim is a task that should either confirm or deny your hypothesis. In an engineering project, your Project Objective may simply be to meet the client's needs and wants, but there may be additional aspects to your project. Your Specific Aims and Project Objectives should be discussed and formulated with your advisor(s) since this step determines what you will work on for the remainder of your project.

For a scientific project, this chapter should consist of a short list of your Hypotheses and the Specific Aim that is related to each. Accompanying the listing of each Hypothesis should be a short summary of your reasons for each Hypothesis (essentially a synopsis of the relevant part of the literature review). Any assumptions that you make in formulating your Hypotheses should be stated in the summary paragraph. The Specific Aim should follow the summary.

In an engineering project, this section should consist of your Project Objectives and Project Specifications. Each Specification should have a short justification accompanying it so that the reader can understand the rationale for each Specification. Again, assumptions should be stated in the Specification justification.

Hypotheses - Scientific Projects

First, base your hypotheses on the information you have gathered from your preliminary research including background material you found in the literature or by talking to other experts working in the field. Second, define your hypotheses. State your hypothesis in one sentence; for example: "Application of strong magnetic fields to a broken limb will speed the healing process." From reading just this one sentence, what you intend to explore in your project is clear. Third, you must be able to test your hypotheses. If you are planning to investigate whether or not the application of magnetic fields speeds up the healing of bone fractures, you must be able to conduct experiments to test this specific hypothesis.

Remember that your hypotheses are only assumptions or educated guesses. You may find the results of your investigation do not support and may even rule out your hypotheses. Do not consider your project a failure if your investigation does not confirm your original hypotheses. Your results are valid and may be helpful in providing you or others with ideas or clues for further investigations.

Project Objectives - Engineering Projects

Hypotheses can also be used in engineering projects, but more often Project Objectives are used instead. Your Project Objectives should be based on both the information you have gathered from your preliminary research (including background material you found in the literature) and by talking to your client(s) (i.e., your client statement).

Assumptions

Every hypothesis carries with it a set of assumptions. For example, in your reading of the background literature you might find that the probability of interaction A is much smaller than interactions B, C, and D. Therefore, you decide to omit interaction A from your model. Your hypothesis is, then, that interactions B, C, and D are the crucial ones. By doing this, you are assuming that interaction A is not important to the process you are studying. This may, however, be a bad assumption. In fact, interaction A, though small, may be crucial to the process. Identifying the assumptions made in your work is crucial to the refinement of hypotheses and for recommendations of future work. In addition, your Conclusions chapter will discuss these assumptions and how they influence the interpretation of the results.

Specific Aims/Project Specifications

After you have identified the problem, discussed what others have done, and made hypotheses, you need to spell out exactly what this particular project is supposed to accomplish, i.e., your Specific Aims. The Specific Aims for a scientific project should be tied directly to your hypotheses. Therefore, if one of your hypotheses is that "muscle cells will multiply fastest in media whose ph is 7," then one of your Specific Aims should be to design and conduct an experiment to test this hypothesis. Each hypothesis should have a Specific Aim attached to it.

For an engineering project, the Project Specifications can be a list which details the exact specifications (including accuracy or performance) of the instrument/device you intend to design. For example, "One Specification of this project is for the spectrometer to have a drift of no more than 5 ppm/hr as specified by our client." This, however, need not be your only Project Specifications. The idea, however, is that the Project Specifications are concrete goals that you intend to achieve. In your Discussion and Conclusions, you will be going over your Project Specifications point by point and will detail how well your results met your Project Specifications.

CHAPTER 4—DESIGN

Scientific Projects
In scientific projects you will be designing experiments to test the hypotheses you have developed. In this chapter, you should list and discuss the design procedures used to decide which experiments will be performed.

Engineering Projects
Engineering MQP's usually involve the design of a hardware/software product. The Design chapter, therefore, should list and discuss the design procedures of various components/systems starting with the design goal of each component. To start, you need to develop a design concept and describe how you tested this concept.

For both types of projects you should detail the sources of the information used in your design process. By referring to reputable sources you raise the credibility of your design. Even statements such as, "We called Jeffrey T. Spaulding, chief engineer at Spaulding International, who told us that PVC tubing would be sufficient for our purposes" are important information for the reader and other researchers.

This chapter should include some of the following material as appropriate:

Needs Analysis and Specifications: One of the most important tasks in design is to determine, as precisely as possible, what the actual requirements are. Therefore, you need to discuss with the prospective users or recipients of your results their "needs and wants". In the context of design, "needs" refers to properties that your result must have. Examples would be: 1) a voltage drift of less than 0.05 mV/hr over 12 hours or 2) the diffusion coefficient of water in the liver measured to a precision of 0.1×10^{-5} cm^2/s.

"Wants" refers to things that you would like to have, but that may not be possible given other constraints. One way to sort out the needs and wants pertaining to your design is to list them in a design matrix and assign weights to the different entries. Using weighting factors can help you prioritize the entries according to a certain scale (e.g., 0 to 10, with 10 being the most important). This method is discussed in the book *Engineering Design: A Project-Based Introduction* by Clive Dym and Patrick Little (2000). Once you have discussed the functional needs, you must also discuss physical limitations (size, weight, etc.) which, together with needs, helped you to define the specifications of your end product or experiments.

Feasibility Study: Although this was investigated in the design process, at some point in the project an assessment has to be made of whether or not the experiments can be performed or the device manufactured given the limitations of the project budget and duration. This is not always possible to determine from the initial design since, in almost every project, changes to the original specifications are made as the project progresses and your understanding of the problem deepens. At some point, therefore, tests might be performed to determine the feasibility of the project. A feasibility study can be used to eliminate different approaches to the project that pass the needs/wants tests, but that, for example, may be too costly given the budget constraints of an MQP. If you performed tests to determine the feasibility of the final design, these tests should be documented in this chapter.

Alternative Designs: Here you should discuss how you got to your final design. Alternative designs should be detailed as well as information used to decide for or against your preliminary designs. Include information acquired from patents, publications, or brainstorming with your partners. Scanned pages from your notebook are relevant and can either be included in this chapter or in an Appendix and merely referred to in this chapter. This material should be treated as a comprehensive answer to the question, "How did you come up with your final design?"

Modeling: Each design reaches a point at which decisions must be made about the material to use, the dimensions of parts, the components of a complex system, or the relationships among different components of a system. Here you should describe any physical models, mathematical models, or real-time computer-based simulations that you utilized to test your design.

Decisions: Design depends heavily on making decisions. Here you should describe, in a systematic way, how you made different decisions concerning your design. For example, the order in which the components were designed, the inter-relationships among components, and the selection of materials all involve decisions. One method to describe the decision process is to use a decision matrix.

Optimization: Here you should discuss the process of selecting a set of specifications, such as dimensions and material characteristics that resulted in the best product or experiment for the particular design configuration chosen.

Preliminary Data: If, in your design process, you have either conducted preliminary experiments or built models and used the data obtained from these to decide on a design, then this data should be included in this chapter. Did the Preliminary Data make you go back and rethink your design?

Part II - Methods and Results

The last five chapters constitute the Methods and Results part of your report. In this part, the goal is to present what you did, how you are interpreting the results, and what should be done in the future. Because you will be writing these chapters and sections after the project has been completed, they will necessarily be in the past tense. Note that the chapters for the results and your discussion of these results are separate. This separation allows you to draw on all of your results in your discussion and allows easier discussion of the big picture.

CHAPTER 5—METHODS

This chapter is at the heart of the project. It should convince the reader that the author clearly understood the problem and has pursued a logical task-sequence to achieve the project's objectives. By describing how the Specific Aims were met, this chapter explains how the project was conducted.

It is important to provide the reader with enough information so that he or she could reproduce your project work. In this chapter it is better to err on the side of more detail rather than less. Think of this chapter as a tutorial for new people in your group. If you wanted them to repeat your work, what information would you have to provide?

This chapter should include material on both your experimental methods your data analysis. To describe your experimental methods, use a clearly defined sequence of tasks. Divide major tasks into sub tasks, which you may tabulate, or represent graphically with GANTT or PERT charts. GANTT charts are discussed in the book *Engineering Design: A Project-Based Introduction* by Clive Dym and Patrick Little (2000).

For an engineering project "data analysis" will include all of the testing that was done on the final device to ensure compliance with the Specific Aims. For example, "We measured the voltage drift over a 12-hour period five times and computed a mean and standard error of the mean" includes information on both the experimental method and the data analysis.

Some projects evaluate alternative methods to achieve a desired end. In that case, what criteria were used to evaluate the alternatives? What specific measures were utilized to gain insight into these criteria? (A matrix, detailing the criteria and measures on one dimension and the alternatives considered on the other, may be a valuable table to include in this chapter.)

CHAPTER 6—RESULTS

This chapter presents the raw results of the project. "Results" can mean different things for different types of projects. A result could be data, findings, or tests of designs. For example, if your project measures the blood glucose levels from a number of subjects, this is the chapter to report what the levels were for each patient at each time point, what the average levels were over the entire group and what the associated errors were that you calculated for the study. This material should flow logically and, if possible, should report the results in the order in which you did the experiments. So, for example, the results of your experiments in which you first calibrated your instrument should be reported before the final results of the study. The structure of the chapter should be very similar to that of procedure/methodology, since these are the actual outcomes of the procedures outlined there. The key is to keep the presentation of the results separated from their discussion. The meaning and significance of your results should be discussed in the Analysis and Discussion chapter, not here.

If your project contains multiple parts, each with its own results, begin your Results chapter with a summary of the total set to provide your reader with an overview. The overview should be written as simply as possible - go for the big picture - this is not the place to get bogged down in the details (which should have been presented in the Experimental Methods chapter). Remember that you are giving the reader only a reminder. If your project focuses on only one experiment, you do not need to provide an overview.

The actual numbers that you measured (along with their associated errors) should be presented next. Again, present your results in a logical order. When you write, imagine that you are explaining your project to someone who knows nothing about it and the logical order will be evident.

If you performed any additional statistical tests on the data after you acquired it, present these results last. Again, it is not a bad idea to present things in the order in which you did them (unless, for example, you forgot to calibrate your instrument and had to go back and do it at the end).

CHAPTER 7—ANALYSIS AND DISCUSSION

This is the part of the report that requires you to decide what the results of your project mean. Your goal in this chapter should be to place your results in the context of previous work and have the reader understand the unique aspects of what you have done. In this chapter you should strive to convince the reader that you fully understand the problem and that you have thought seriously about what your data means. In general, you need to discuss each of your results separately, discuss each of your assumptions and how they influence the interpretation of the results, and build a logical argument that convinces the reader of your point of view. In addition, this chapter sets the stage for the conclusions drawn in the final chapter.

In a scientific project, this chapter convinces the reader that you have met your Specific Aims and that your results prove (or disprove) your hypothesis. Remember that your Specific Aims are the goals for your experiments and these should be met whether or not your hypotheses turn out to be true. In an engineering project, this chapter convinces the reader that you have met your Project Objectives/Specifications.

This is also the chapter where you discuss how your results compare with those found by others (the latter should have been discussed in the Literature Review). For an engineering project, this chapter examines how the performance of your designed instrument or device compares with other existing devices. If you made measurements, you should discuss what your values mean in light of other work that has been reported previously. For example, is your value significantly less than the currently accepted value? If so, you should provide possible explanations. If your results differ from other published results, you need to explain these discrepancies. Your explanation might consider differences in materials, experimental methods, data analysis or any other factors you feel are relevant.

Additionally, this chapter discusses limitations of your data. Such a discussion usually will diffuse any criticism of these limitations, because you will have acknowledged them and discussed how either they are not critical to the success of your experiment or that your data is meant to address a limited aspect of a problem.

CHAPTER 8—CONCLUSIONS

In this chapter your goal is to draw global conclusions about your results. Therefore, you should summarize the big picture for the reader, what your results mean and what you have accomplished by your work. Numerical results are not necessary in this chapter.

The conclusions and the abstract contain similar information; however, their goals are different and, as such, the presentation of the information is different. As noted above, numerical results are necessary in the Abstract, but not in the Conclusions. Another difference is that there should be no interpretation or discussion in the Abstract, just a statement of the main result, while the Conclusions should be a summary of your interpretation of your data.

CHAPTER 9—RECOMMENDATIONS

Recommendations are a logical consequence of the conclusions. They suggest remedial actions to some problem or further in-depth studies in some specific areas. In this chapter, you should write about all of the things that were left undone either due to lack of time, finances, or equipment. A good project should always point the way to the next problem to be solved or measurement to be made. Suggesting things that might be done to carry on your research indicates that you understand the problem you are working on.

REFERENCES

This section lists any sources you have consulted, whether they are print, electronic, or personal communications. Reference any facts in your report that you have not directly verified and that are not immediately obvious to the layman. For example, if you state that heart disease is the number one cause of death for adult males over the age of 65, you should provide a reference for this fact. If, however, you state that WPI is located in Massachusetts, you need not supply a reference.

The References section should be written according to common practices, i.e., there are many permissible styles of writing reference entries – do not invent your own. Ask your advisor(s) about common styles in their field or look at journal articles that you used to write the Literature Review chapter. One common style is shown below:

Marx, G., Marx, C., Marx, H., and Marx. Z., "Hail Fredonia! A Critical Review of the Representation of National Governments in Film, 1930 – 1950." *Film Review Quarterly*, **16**, 1100 –1125 (1964).

Include sources for figures in your References as well as listing the source in the figure caption itself. In addition, any conversations or interviews that were conducted should be referenced.

GLOSSARY

The non-specialist reader normally will not understand the technical vocabulary necessary to describe your project and its results fully. Therefore, it is often helpful to add a Glossary section. When a technical term is first used in the text, briefly define it, then refer the reader to the Glossary for a fuller explanation.

APPENDICES

Use Appendices for important material that is too voluminous and digressive for inclusion within the project text. For example, if you have written computer code that is important to the project, you should include it as an Appendix. If you have done some calculations that are somewhat peripheral to the project, or have come up with a new way of looking at a derivation, put it in an Appendix. All material placed in an Appendix must be referenced within the text of the project. Where necessary, separate Appendices should be used - rather than one large Appendix - to facilitate easy reference to the materials. Each Appendix should be lettered (i.e., A, B, C...), given an appropriate title, paged, and included -- with appropriate title and page -- in the Table of Contents.

Writing Help

If you would like to discuss a draft of your document with a writing consultant, make an appointment with WPI's writing workshop (www.wpi.edu/+writing). For information about registration procedures, go to www.wpi.edu/Academics/Projects/started.html.

Last modified: January 13, 2004

Sample MQP title page

Project Number:<BME-0903>

<ANALYSIS OF A BIOMEDICAL IMPLANT MATERIAL TO ALLEVIATE BACK PAIN>

A Major Qualifying Project Report:

Submitted to the Faculty

Of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

<student(s) signatures>

<students names>

Date: <enter date of submission>

Approved:

< signature of major advisor >
Prof. <Otis P. Driftwood>, Major Advisor

1. pain
2. lumbar
3. nerve

< signature of co-advisor >
Prof. <Quincy Adams Wagstaff>,Co-Advisor

Sample Table of Contents

Biomedical Engineering Department

MQP Review Form

Project Title: ____

____

Student(s): ____
(list outside ____
departments) ____

Advisor(s): ____
(list outside ____
departments) ____

Number of Pages: ________

Additional Materials (e.g., CD's): ____

Sponsorship: Faculty research__________ External:__________

Was the project presented orally? Project Presentation Day____ Other Department_______
No presentation_______

Please rate the items listed below based on the following scale:

N/A = Not Applicable
N/F = Not Found
1 = Severely deficient
2 = Deficient
3 = Adequate
4 = Good
5 = Excellent

I. Please rate how does the MQP demonstrate the following outcomes and assessment criteria?

(a) An ability to design and construct experiments on living and non-living systems (2.1):

Please rate the extent to which design goals were clearly stated.	**N/A 1 2 3 4 5** **Pages:________________**
Please rate the extent to which the MQP addressed the design and implementation of effective experiments on living systems.	**N/A 1 2 3 4 5** **Pages:________________**
Please rate the extent to which the MQP addressed the design and construction of effective experiments on non-living systems.	**N/A 1 2 3 4 5** **Pages:________________**
Please rate the extent to which tests, simulations, and measurements were made in a structured manner.	**N/A 1 2 3 4 5** **Pages:________________**

(b) An ability to analyze and interpret experimental data (2.2):

Please rate the extent to which appropriate statistical techniques were applied to analyze and interpret data.	**N/A 1 2 3 4 5** **Pages:________________**
Please rate the extent to which data were analyzed in a valid and meaningful way.	**N/A 1 2 3 4 5** **Pages:________________**
Please rate the extent to which observed results, correlations, unexpected outcomes and unmet specifications were fully explained.	**N/A 1 2 3 4 5** **Pages:________________**
Please rate the extent to which data limitations were considered.	**N/A 1 2 3 4 5** **Pages:________________**
Please rate the extent to which the conclusions were supported by analysis.	**N/A 1 2 3 4 5** **Pages:________________**

(c) An ability to design systems, components and processes to meet desired needs (2.3):

Please rate the extent to which the design goals were clearly stated.	**N/A 1 2 3 4 5** **Pages:**__________________
Please rate the extent to which the students synthesized material from various sources in their design.	**N/A 1 2 3 4 5** **Pages:**__________________
Please rate the extent to which the students considered and incorporated a variety of realistic constraints including: economic factors, safety, reliability, and aesthetics.	**N/A 1 2 3 4 5** **Pages:**__________________
Please rate the extent to which the design process demonstrates critical, original, and creative thinking.	**N/A 1 2 3 4 5** **Pages:**__________________

(d) An ability to function in a multidisciplinary team (2.4):

Did the project involve participants (students or faculty advisors) from other majors or disciplines?	**yes no** **Pages:**__________________

(e) An ability to identify, formulate and solve BME problems (2.5):

Please rate the extent to which the students established that they had correctly identified the problem through interviews with stakeholders.	**N/A 1 2 3 4 5** **Pages:**__________________
Please rate the extent to which the students established clear objectives for the problem.	**N/A 1 2 3 4 5** **Pages:**__________________
Please rate the extent to which the students considered reasonable alternative solutions.	**N/A 1 2 3 4 5** **Pages:**__________________
Please rate the extent to which the proposed solution was implemented effectively.	**N/A 1 2 3 4 5** **Pages:**__________________
Please rate the extent to which the end results were consistent with the original specifications.	**N/A 1 2 3 4 5** **Pages:**__________________

(f) An ability to communicate effectively (2.6):

Please rate the clarity and logical organization of the MQP report.	**N/A 1 2 3 4 5**

Please rate the quality of grammar and style.	**N/A**	**1**	**2**	**3**	**4**	**5**
Please rate the clarity with which complex ideas or arguments are presented using graphs, tables and adequate explanations.	**N/A**	**1**	**2**	**3**	**4**	**5**
Please rate the professional appearance of the MQP report.	**N/A**	**1**	**2**	**3**	**4**	**5**

(g) Understanding the impact of the engineering solutions in a global and societal context (2.7):

Please rate the extent to which the students addressed the potential effects of their work on the well-being of people, animals, and the environment? **N/A 1 2 3 4 5**
Pages:__________________________

(h) Knowledge of contemporary issues (2.8):

Please rate the extent to which the MQP report addressed an important contemporary biomedical issues.	**N/A**	**1**	**2**	**3**	**4**	**5**
Please rate the extent to which the MQP was influenced by contemporary biomedical issues.	**N/A**	**1**	**2**	**3**	**4**	**5**

(i) Use of modern engineering tools (2.9):

Please rate the extent to which the students used appropriate state-of-the-art design, computer simulation, analysis or presentation software, manufacturing techniques, evaluation techniques, etc. in their MQP. **N/A 1 2 3 4 5**

(j) Demonstrate an understanding of professional and ethical responsibilities (3.1):

Please rate the extent to which relevant ethical issues were identified and addressed. **N/A 1 2 3 4 5**
Pages:__________________________

(k) Recognize the need for and have the ability to engage in life-long learning (3.2):

Please rate the extent to which the references demonstrate an ability to gather data from a wide variety of professional sources. **N/A 1 2 3 4 5**
Pages:__________________________

Please rate the extent to which the literature review demonstrates that the students can integrate effectively ideas from a variety of sources.	**N/A**	**1**	**2**	**3**	**4**	**5**
	Pages:____________________					

II. Please rate the quality of various sections of the MQP report:

TITLE PAGE	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
TABLE OF CONTENTS	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
AUTHORSHIP PAGE	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
ABSTRACT	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
TABLE OF FIGURES	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
TABLE OF TABLES	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
INTRODUCTION	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
LITERATURE REVIEW	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
SPECIFIC AIMS	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
PROJECT APPROACH	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
DESIGN	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
METHODS	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
RESULTS	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
ANALYSIS AND DISCUSSION	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
CONCLUSIONS	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
RECOMMENDATIONS	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
REFERENCES	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
GLOSSARY	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**
APPENDICES	**N/A**	**N/F**	**1**	**2**	**3**	**4**	**5**

III. Capstone Design Content

To achieve a Capstone rating, the project must substantially include the first 5 elements listed below, but does not have to include fabrication and testing.

Did the project show that an open-ended need existed for a device, system, process, or experiment?	**N/A**	**1**	**2**	**3**	**4**	**5**
Was the problem defined and the design criteria stated fully?	**N/A**	**1**	**2**	**3**	**4**	**5**
Were alternative designs created and reviewed?	**N/A**	**1**	**2**	**3**	**4**	**5**
Was at least one design analyzed?	**N/A**	**1**	**2**	**3**	**4**	**5**
Was the final design discussed or refined in terms of meeting design criteria?	**N/A**	**1**	**2**	**3**	**4**	**5**
Was the final design fabricated?	**N/A**	**Yes**	**No**			
Was the final design tested?	**N/A**	**Yes**	**No**			
Is the design sufficient to satisfy the Capstone design?	**N/A**	**Yes**	**No**			

Reviewer's Comments:

Biomedical Engineering Department
Evaluation of MQP Presentation

Date: ___________________

Project Title: ____

____

Name of Student(s): ___________________________ ___________________________

___________________________ ___________________________

Reviewer's Name: ___________________________

Form of Presentation:

Poster _________ Oral _________

Please rate the items listed below based on the following scale:

N/A =	Not Applicable	3 =	Adequate
1 =	Severely deficient	4 =	Good
2 =	Deficient	5 =	Excellent

1. Content:

a. Project objectives were stated	**N/A**	**1**	**2**	**3**	**4**	**5**
b. Key ideas were explained	**N/A**	**1**	**2**	**3**	**4**	**5**
c. Presentation ended with a conclusion	**N/A**	**1**	**2**	**3**	**4**	**5**
d. Overall organization of the presentation	**N/A**	**1**	**2**	**3**	**4**	**5**

2. Presentation Skills:

a. Presentation was delivered with enthusiasm	**N/A**	**1**	**2**	**3**	**4**	**5**
b. Students used visual aids	**N/A**	**1**	**2**	**3**	**4**	**5**
c. Students used prototype/model demonstrations	**N/A**	**1**	**2**	**3**	**4**	**5**
d. Quality of visual aids	**N/A**	**1**	**2**	**3**	**4**	**5**
e. Presentation demonstrated effective teamwork	**N/A**	**1**	**2**	**3**	**4**	**5**
f. Handling of Questions	**N/A**	**1**	**2**	**3**	**4**	**5**

Reviewer's Comments:

Summary of MQP-related Discussions During BME Department Faculty Meetings

October 8, 2002
EBI Survey
The results of the latest EBI survey were presented. One area of concern was the student's exposure to social, environmental, and political issues in their major design experience. These issues and ways to improve these areas were discussed. The MQP tutorial document will be examined and, if necessary, modified to make students more aware of the extra-technical issue of design.

October 22, 2002
MQP Report Review Results
The results of this year's review were discussed. In general, the quality of the reports improved, though there were still a few reports that were not prepared that carefully. The issue of groups advised by people outside the department was discussed. The problem is that we need to make sure that all of our students meet the BE requirements and outcomes and, since we are using the MQP as a major evaluation source, students who follow the guidelines of other departments may not be meeting all of our requirements. The issue of whether or not the reviewer should decide whether the project merits the Capstone Design designation was also discussed. This is an issue because the advisor decides this question before the review. ME faculty who regularly advise BE students will be queried on this issue. The MQP reviews for the projects that included BE students will also be requested from the ME department.

December 16, 2002
ABET Visit - Exit Interview Notes:
The department needs a document that outlines our MQP requirements. This document would be given to students doing projects in other departments and those advisors.

November 17, 2003
MQP Review Results
The results were discussed. The issue of reports missing required sections was discussed. The main issue of discussion was that of the Capstone Design designation. The issue is that ABET requires that we be able to demonstrate that each of our students have had a Capstone Design experience. We rely on the MQP to provide that experience. In the past this was an issue with projects done outside the department; however, some program advisors are now asking their students to use the format laid out in the BME tutorial document. The question of what would constitute a "not passing" grade in regards to the Capstone Design was discussed. There are two possibilities: 1) there is some design in the project, but it is minimal and not discussed fully in the report and 2) there is a full design analysis, but it is poorly done. The issue then becomes: Is a poor design and execution different from not actually doing the design work? It was generally agreed that in case 2), the project would still receive the Capstone Design designation (though it was raised that it might be difficult to decide upon the difference). The poor quality should

already be reflected in the advisor's grade. It was suggested that deliverables at specific deadlines might help since problems could be remedied early in the project. One side issue that was then discussed was what would happen in the case that the group turned in a design deliverable that was sure not to meet the Capstone Design requirements? Is the group given an "NR" for the term?

There were several suggestions for the remediation of this problem:
1) Have the students keep notebooks. The reviewer could then request the notebooks in the event that the Design is found to be deficient in the report. The reviewer could then determine if the design was fully realized and analyzed in the notebooks, just not in the report. If this were the case the report would still get the Capstone Design designation by the reviewer.

2) A talk and discussion session could be given each year (in A or B term) on the departmental requirements for the MQP report. One faculty member agreed to this noted that he had done it in the past. He has also met with students on an ad hoc basis.

3) The reviewer should have the option to ask the faculty member for further information if the project is going to receive a "No Capstone Design" designation.

4) A form that has specific goals for Design to be filled out by the students and handed back to the advisor at the end B term. This would alert the advisor to any red flags early on. Such a form will be created for B2004.

It was asked that the Tutorial be revised in re: sentences addressing the issue of hypotheses for engineering projects. The reviewer noted that he was more interested in seeing Specific Aims for engineering projects and that he did not have text in the tutorial that allowed the engineering projects not to have hypotheses, because in some cases they could be applicable.

January 13, 2004
<u>Announcements:</u>
It was noted that the latest MQP tutorial is finished and will be up on the web if there are no further comments.

<u>MQP Requirement Document</u>
A draft of such a document has been written and was distributed to the faculty before this meeting. Some suggestions on the text were discussed. The issue of enforceability was raised. Is this a contract? And what is its utility if it is unenforceable? The student passes based on the grade, the signature on a CDR form and a check in the capstone design box. BME can't do anything if an outside advisor says that the project passes and meets the Capstone Design requirement. It was suggested that this draft be distributed to outside advisors and see if they were comfortable with its contents. The draft will be sent out to all Program faculty and comments solicited.

The issue of MQP design notebooks was then discussed. The issue of intellectual property and compliance from faculty outside the BME department was discussed. The issue was one of what happens if the reviewer thinks the project did not fulfill the Capstone Design requirement, but the faculty advisor thought it did. The notebook could be used as evidence of work that was performed, but that, for some reason, did not make it into the MQP report. It may be that in the future we need to address this issue in a different way (i.e., another design course), such that the burden of fulfilling the Capstone Design requirement does not fall solely on the MQP. The notebook idea will be put into the Departmental Requirements document ('to help facilitate the documentation of the design process these notebooks will be available from the departmental office and will become the property of the Department upon completion of the project').

Addition of material on Academic Honesty to the document was then discussed. It was noted that it is difficult to globally define dishonesty for this/a document since what is ok in some situations is not in others (ie, working together). It was agreed that the addition of material on Academic Honesty was not appropriate for this document.

January 29, 2004
<u>Response from Affiliate Faculty MQP Requirements Document</u>
The comments on the draft document of one Program Faculty member were discussed. The problem with the document was with the required format of the MQP report. It was agreed that the format of the report would be secondary as long as the Design section met the Capstone designation. Other issues were also raised and a representative of the BME department will meet with the faculty member to discuss this issue.