Worcester Polytechnic Institute

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

BIENNIAL REVIEW OF MQPS

Robert Labonté and William Michalson

February 2, 2007

1. INTRODUCTION

This document summarizes the findings of a review of ECE department Major Qualifying Projects that was conducted during the Fall and Winter of 2006-2007. This is the eighth such review being undertaken to assess the condition of this portion of the ECE degree program at WPI.

As was the case with the previous ECE department MQP reviews, it was concluded that the most effective review procedure should involve reading all of the project reports for ECE MQPs conducted during the 2005 - 2006 academic year. For the purpose of this review, the period was defined to include MQPs completed during E05, A05, B05, C06, and D06. A total of thirty projects were completed during that period.

During the review, a set of summary sheets were completed for each project. For consistency with prior year data, these sheets included the same two sheets that have been used in the department since the 1991 MQP review. In 2001, an additional WPI-created sheet was filled out which was specific to assessing ABET-related criteria: Abet Criterion #3 and ABET Capstone Design. While this data was normally collected by separate means as part of a campus-wide WPI ABET review process, such an evaluation was not available for this review. However, to achieve consistency, these ABET-like data were estimated as part of this review and are included in the analysis that follows. A copy of the summary sheets used is included as Appendix 1.

In addition, the CDR forms for each student were also included to permit project grading, and credit awarded to be considered.

Wherever possible and meaningful, the results of this review have been compared to those that resulted from the previous ECE reviews. The detailed statistical data upon which this review report is based are contained in a separate document. Individual project summary sheets are considered to be private and have been destroyed.

The overall quality of ECE department MQPs has been found to be quite good with more than 83% of projects being functional. We find no question regarding the continued educational value of this degree requirement. The range of topics along with the exceptional quality observed in many of them and the extent of external interest and sponsorship experienced is truly impressive. Even so, an integral and significant component of this review has been to identify areas where the MQP process should be modified or emphasized to further enhance the value of the MQP's contribution to the overall educational experience.

2. OUTCOMES ASSESSMENT CONTEXT

2.1 Goals of WPI’s Undergraduate Program in Electrical Engineering

Endorsed by the ECE faculty in May of 1997, the following statement defines the goals of the department in terms of the undergraduate program as well as providing the context for those assessments needed to assure desired outcomes.

> *The electrical and computer engineering department educates future leaders of the electrical engineering profession with a program characterized by curricular flexibility, student project work, and active involvement of students in their learning. Through a balanced, integrated electrical engineering curriculum, we provide an education which is strong both in the fundamentals and in state-of-the-art knowledge, appropriate for immediate professional practice as well as graduate study and lifelong learning. Such an education also prepares students broadly for their professional and personal lives, providing the basis for effective leadership and informed citizenship. The curriculum embraces WPI’s philosophy of education, and takes advantage of key components such as the Interactive Qualifying Project and Major Qualifying Project to develop technical professionals who possess the ability to communicate, to work in teams, and to understand the broad implications of their work.*

2.2 Specific Educational Objectives of the Electrical Engineering Program

The educational objectives of the electrical engineering program are as follows:

1. Preparation for engineering practice, including technical, professional, and ethical components,

2. Preparation for the future changes in electrical engineering,

3. A solid understanding of the basic principles of electrical engineering,

4. An understanding of appropriate mathematical concepts, and an ability to apply them to EE,

5. An understanding of the engineering design process, and an ability to perform engineering design, including the needed teamwork and communications skills,

6. Demonstration of in-depth understanding of at least one specialty within ECE,

7. Demonstration of written and oral communications skills,

8 Understanding of options for careers and further education, and the necessary educational preparation to pursue those options,

9. An ability to learn independently,

10. The broad education envisioned by the WPI Plan, and described by the Goal and Mission of WPI, and

11. An understanding of electrical engineering in a societal and global context.

3. SUMMARY OF PROJECT CHARACTERISTICS

3.1 Project Team Makeup: Students and Advisors

The average student project team size was 2.50, approximately the same as the average of 2.35 in the previous review. Thirteen percent of the reviewed projects were accomplished by a single student. Thirty-seven percent consisted of two-student teams; thirty-seven percent consisted of three-student teams; and thirteen percent consisted of four-student teams. There were no teams larger than four students. This is an encouraging trend since during previous years the percentage of single person teams ranged as high as 48% and there were often teams containing an excessively large number of students. For reasons of advising efficiency and pedagogy (hands-on experience working as part of a team) single person projects have historically been discouraged.

3.2 Academic Level and Topical Content

The academic level—freshman, sophomore, junior, senior, and graduate level—of the electrical engineering, computer science and mathematics content of the projects was estimated from the related information presented in the project report. The estimates made using a scale of 1 to 5 (1 for 1000-level courses, 2 for 2000-level courses, 3 for 3000-level courses, 4 for 4000-level courses, and 5 for graduate-level courses).The average value for ECE course content was estimated by the review committee to be 3.8, a slight increase from 3.7 for the previous review, providing strong evidence that junior and senior level course content was evident throughout. These results are fully consistent with our expectations for the MQP and have remained at approximately this level since these reviews began.

First tracked in the 1994-95 review, the ECE review has continued to evaluate the Computer Science content of MQPs. The average value for Computer Science course content was estimated by the review committee to be 2.3, a slight increase from the level of 2.1 obtained in the previous review. Considering that programming in C and Assembly language along with the techniques of program design are at the 1000 and 2000 level, with machine organization, computational paradigms, and algorithms at the 3000 and 4000 level, these results appear to indicate that fewer students are either taking the more advanced computer science courses or that they are not generally applying this more sophisticated computer science material to their ECE projects.

The mathematics content of MQPs was estimated by the review committee to be 2.1, the same as that observed during the previous review. This is the lowest level determined since the 1997-98 review. As with the previous reviews, the low-level of mathematics content continues to remain a matter for concern. The view here is that the lack of mathematics continues to be a result of incomplete discussions of the phenomenology associated with the project topic and of incomplete documentation of the theoretical justification of design solutions.

The projects were also analyzed with respect to sub-areas within electrical and computer engineering. The areas with the largest representation were analog electronics (70%), computer engineering (53%), software (50%)), signals and communications (40%) , and E&M (30%). Note that the totals can be greater than 100% because many projects involved more than one sub-area. When compared with the results of prior reviews, the sub-areas with the largest representation were computer engineering (67%), analog electronics (54%), software (36%) and signals and communications (28%). Clearly, there has been a significant shift in the topical areas pursued in MQPs relative to previous years. However, because the large number of analog, communications and aerospace sponsored projects undertaken during the current review period, this result is not surprising.

The presence of several specific components of the engineering process was also reviewed; these are: measurement and analysis, hardware design and construction, software design and implementation, computer simulation, and the use of other computer devices such as embedded microprocessors. In general, the process components of measurement, analysis and hardware design are extremely well represented with 97% (up from the most recent prior review level of 80%) of projects accomplishing "much" or "very much" measurement and analysis, and 60% (up from the most recent prior level of 50%) of projects accomplishing "much" or "very much" hardware design. Other components appeared as follows: software design was 61% (up from 38%), computer simulation was 61% (up from 35%), and other computer usage was 51% (up from 35%). Clearly, all areas showed significant gains. As was the case in prior reviews, “other computer usage” was interpreted to mean that the MQP either contained an embedded processor or that a computer peripheral to the MQP was used to test or analyze the project.

It is encouraging to see the sustained increase in computer simulation in many projects. It is possible that an increase in larger projects which could not be completed in a single MQP lead to a tendency to perform somewhat less actual hardware design and more modeling/validation. These increases reverse the trend seen in the past four reviews and represent a positive change way students are approaching their work.

3.3 Grade Distribution

The current grade distribution appears to indicate that the return of grade inflation noted in prior reviews is still present. The number of students receiving A grades was found to be 87% (above the previous record high of 78%). In this period, the number of B grades was 11% (as compared to 15% in the most recent prior review) and the number of C grades was 3% (as compared to 8% in the most recent prior review).

It appears that the large number of A grades relative to the number of B and C grades remains related to the number of projects that were judged to be worth 1 unit of credit per student. In this review, it was determined that 33% of the projects completed were marginally worth 1 unit. However, It must be emphasized that an A grade should reflect one unit of excellent work by the student, a B grade should reflect one unit of very good work, and a C grade should reflect one unit of acceptable work.

There is also a clear tendency to assign all students in a project team the same grade. Only 7% of projects had teams in which different students were assigned different grades.

As with previous reviews, in those cases where it was judged that the grades awarded were marginally justified or unjustified by the work reported, the causes were typically the same. Such projects often had minimal design justification, poor or limited documentation of the design process, and little or no substantive engineering analysis to support the design approach followed.

3.5 Overall Academic Merit

The majority of project reports were judged to represent academically solid projects that clearly met the expectations established for this degree requirement. As well, overall technical quality was found to be consistent with reasonable expectations for bachelor-level performance. Unfortunately, based on observations of actual student work versus the work reported in the MQP documentation, the documentation does not appear to capture the extent of the work actually done. In many cases, it was known that work done by the students was much more sophisticated than was reflected in the documentation. However, it was necessary to rely only on the material presented in the report to judge the various review elements. This is consistent with the type of review that would be done by an ABET reviewer.

In the 1994-95 review, all instances where marginally acceptable work was observed were with projects for which a C grade was given to the students. As of this and the previous three reviews, this is no longer the case since projects at all grade levels were judged marginally worthy of a unit of credit. It must be noted here that reviewer judgments were made on the basis of the documentation provided and not on any independently obtained knowledge of actual student performance. In evaluating the documentation of projects in this marginally acceptable category, the following types of problems were noted in one or more reports: poor or no description of specific project objectives, little or no documentation of the selected design approach, little or no analysis to support the design specifics, and relatively little comparison between measured performance and the project goals.

3.6 Project Documentation

The quality of project documentation appears to have dropped slightly since the previous review and is still below the record high performance noted during the 1994-95 review. In this review, the number of reports whose quality was judged as either “good” or “excellent” was 73%, slightly down from a level of 75% in the previous review, and below the record 83% level achieved during the 1994-95 review. The fact that 27% of the MQP documents were rated as having “fair” to “poor” overall quality remains an important deficiency to address. The faculty must be careful to ensure that students develop the skills and discipline to produce documentation that effectively communicates the goals, approach, and results of their efforts.

Before discussing the summary document-quality observations of the review committee, it is important to cite an observation that holds for all of the reports reviewed. In virtually every report, significant grammatical and spelling errors were detected. Unfortunately, any independent reviewer – picking any one of these reports at random – might obtain a poor impression of our overall quality control, especially since that reviewer may not read the entire report. There is no question that we must all be more demanding of our students in the area of documentation quality.

For those reports having problems beyond those just mentioned, the following statements reflect summary assessments related to the criteria used by the review committee to evaluate project reports.

- <u>Design, Test, and Performance</u>. In each of these categories the descriptions in the MQP report have tended to be far more vague than in prior years. While each of these categories received approximately the same amount of attention as in the previous review, the level of detail was far less. It is important that students be able to clearly articulate their design justification and to articulate test procedures and performance results. For those reports where these criteria were judged marginal or poor, the typical problem was either the total lack of test data and project operability or the inclusion of only a sentence or two on the topic in the conclusions section.

  ECE 2799 , Electrical Engineering Design, was created specifically to address these types of deficiencies by teaching students the logical methodology that should be followed in the synthesis of any design from its overall specifications. Many of the reports indicate that a trial design was developed based on the best efforts of the project team. Typically, as the reports freely describe, that initial design did not achieve the objectives. Effort was then directed toward finding adaptations to overcome observed deficiencies – typically a process that dominates the team's efforts for the remainder of the available time. Sometimes it works and a functional design is achieved. More often than not, it appears that a design was prepared and after initial failure, the team's efforts were directed toward "beating on the design" until some level of operability was achieved.

Because 63% of all projects evaluated during this review fail to employ the design methodology of ECE 2799, it should be no surprise that project functionality is often lacking. We insist that ECE 2799 be accomplished successfully before starting an MQP. We project advisors **must** also **insist** that our MQP teams employ the design techniques they have been taught to use – it is hard work, but – like many things -- it is the type of skill that is best developed through practical usage.

- <u>Literature Review</u>. For this criterion, only 43% of reports reflect a clear effort on the part of project teams to take advantage of archived material (down significantly from the 82.5% achieved during the most recent prior review. 0f the remaining project reports, 53% contained only vague references to such material. One project report contained no mention of a literature review. Since the engineering method we teach always embodies intimate contact with the archived literature, it is essential that we **insist** that all project teams make full use of these assets.

- <u>Economics</u>. In the 1998-99 review only 47% of reports contained any mention of economics as of the 2000-01 review now only 15% of projects have any mention of economic issues. We've nearly eradicated any discussion of economics from the MQP. This is a trend that **must** be reversed. While it appears that our students become sensitized to the importance of economic issues in the design process during ECE 2799, as a faculty we are simply not insisting that these economic decisions get written into the MQP report. We simply **must** insist that design trade-off and implementation decisions—as required by ABET—always include economic considerations as part of decision process.

3.7 Project Sponsorship

This review continues to collect data about the extent to which MQPs are sponsored by external organizations. Of the thirty projects, 53% were sponsored in this manner, similar to the 55% sponsored during the previous review. Sponsoring organizations were: Analog Devices, Bose, NASA and many more. This continued record high level of sponsorship is outstanding.

Among the unique potential benefits to external sponsorship, the following represent some of the features that are not always possible to emulate as well with projects that are conducted entirely within the academic environment:

- The problems being addressed are real, current, and—typically—commercially significant.
- Project goals and objectives are clearly articulated at the outset of the project.
- Students have the opportunity to interact with working engineers who, themselves, have a professional interest in the project.
- Project sponsors typically expect the project team to produce a practical, working design solution.

These are positive benefits that make work on sponsored projects a closer analog to that which students will encounter when they reach the join the industrial/commercial work force. As such, sponsored projects have substantial value. We should make a conscious effort to assure that the current levels of external sponsorship are maintained and, if possible, expanded.

In the context of this MQP review, the relative quality of MQPs accomplished by teams working on sponsored projects and those accomplished for non-sponsored projects was evaluated. No clear differences were expected and none were observed.

3.8 Overall Observations

The project topics represented in this group of MQPs give evidence of the extremely wide range of technologies and applications being addressed. Projects ranged from complex computer-engineering applications to those that were software and mathematically intensive. While a number of these projects represent truly outstanding efforts and achievements by their student teams, it is equally important to stress that the average level of the projects considered by the review committee is still very good.

It is also important to note that this review was conducted with the specific intent of evaluating MQP projects and not their faculty advisors. Hopefully, the results described herein and the areas where improved faculty vigilance and attention is merited will be found to be helpful. It must be emphasized as well that no correlation between weak projects or specific weaknesses and any member of the faculty was observed.

4. CONCLUSIONS

The primary objectives for improving MQPs in the ECE department since the 1995 review were to increase the amount of design synthesis that was presented in the MQP report and to increase the awareness factors such as: economics, safety, reliability and other factors of importance in satisfying ABETs capstone design requirements. Since that time, additional ABET requirements have been established for performing outcome-based assessment of the learning process of our students.

In response to these objectives, the department has concluded that to increase the overall quality of MQPs, especially in terms of design synthesis and ABET capstone design requirements, increasing faculty and student awareness has proven to be insufficient. As a consequence, and as part of an overall curriculum review and refinement by the ECE Undergraduate Program Committee, the design course ECE 2799 was conceived to target these design objectives.

The following is a summary of the major conclusions of this review:

- The general educational goals of the MQP are being met.

- The design content of projects is high – as it should be – and is consistent with capstone-design expectations.

- Some elements of the ABET design definition – namely, factors such as: safety, reliability, aesthetics, ethics, and social impact – are not currently emphasized as well as they should be.

- Documentation quality must be improved substantially. While it appears that students are not following the design methodology that is promoted in ECE 2799., the reviewers of this group of projects can attest that both encountered many instances where students came for help and were indeed following the anticipated design approach. The fact is that such information is not being included in project reports. As a direct consequence, the principal documentation deficiency continues to be a lack of adequate descriptions of the results of analysis, simulation, and trade-off studies used to synthesize the design from established specifications and objectives.

- There continue to be instances where the issuance of one unit of credit is questionable.

- The mathematics and design-simulation levels remain below expectations.

- The trend towards grade inflation seems to be continuing.

The overall conclusion of this review is that while the MQP process and the projects themselves are basically sound and are meeting the educational objectives of the Institute, it is essential that additional attention be paid to capstone design and outcomes-assessment criteria.

5. RECOMMENDATIONS

5.1 Historical Perspective

Having now conducted eight biennial reviews of MQP projects, several general observations appear to be appropriate.

First, once the data from a review are disseminated to the faculty along with suggestions for improvements in areas where faculty or student attention are required, the faculty historically responded appropriately. However, many of the same issues raised in the earlier reports remain issues now. Moreover, we are slipping in some areas. Rather than responding to issues raised in an earlier report when issues such as grade inflation have been noted, the current review indicates that essentially nothing has been done to correct the problem. It is not known if this break in tradition is a result of overloading on the part of faculty, leaving less time to attend to the details of an MQP or if there is some other cause.

Second, problems observed and corrected do not necessarily remain corrected in the long term. Using our grade inflation example, although this problem was under control, the past two reviews suggest the return of grade inflation. Thus, faculty attention must again be focused on making corrections.

Third, the review process cannot be terminated after a few years with the expectation that the overall capstone design process has been optimized. As faculty turnover occurs and department management changes, unexpected new problems can become manifest for, even though a problem might not have been observed through past reviews, there can be no guarantee that it will not appear in the future.

From these observations, and others which could be presented to further highlight the dynamics of the review process, it is evident that there is a need to maintain constant vigilance if we are to ensure that the design element of a curriculum remains optimum. In fact, a cyclic process of review, problem detection, and problem correction must be recognized as essential.

5.2 Specific Recommendations

The following recommendations are offered here for consideration by the ECE faculty: Most of the recommendations proposed here are identical to those mentioned in past reviews. In those instances, the recommendations are intended as reminders to the faculty of important project characteristics.

- All project advisors should expect that the members of the project team will have successfully completed ECE 2799, ECE Design.

- All project advisors should participate as faculty for at least one offering of ECE 2799.

- Every project team should be required to clearly establish a set of specifications and design objectives early in the MQP process. These specifications and objectives should be specific, measurable, and traceable to the phenomenology of the problem being solved.

- In the conduct of projects, material must be developed to demonstrate that the design that will be implemented is theoretically justified. Specifically, analytical results, simulation, and a comparison of analytic and simulated results where appropriate.

- The faculty should make a concerted effort to maintain the number of corporate-sponsored projects.

- The faculty should be mindful that 1 unit of MQP credit is the equivalent of 3 courses for each student involved in the project.

- The faculty must ensure that peripheral issues such as economics, reliability, safety, ethics, and social impact are addressed in the MQP. While it is expected that our design course will increase student ability to address these issues, continued faculty vigilance is essential.

- The faculty must encourage students to fully document their projects from start to finish. This should include the original derivation of a solution, test plans, results, and conclusions. In addition, each report should include an executive summary and an advisor-written one-page summary sheet.

- The faculty should assure that all ABET Capstone Design expectations are satisfied and are addressed in each MQP report. Since the majority of projects focus on designs which parallel or improve on existing products, it is expected that issues such as safety, reliability, economics, and ethics play an important role in the selection of a technical solution. In areas where this is true, it should be highlighted.

- The faculty should provide students with copies of the forms that will be used to assess the overall quality and completeness of their projects. Copies of those forms along with the description of each criterion are included in Appendix 2.

- Recommendation to the ECE Undergraduate Program committee: Sponsor at least two MQP projects that will be conducted by our faculty, principally during E-Term. The rational here is to create models and documentation that can be used by students as examples of the proper application of design synthesis methodology and reporting.