Caltech SFC 2009: ACM Committee Final Report

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1 Introduction

The Applied and Computational Mathematics undergraduate option is relatively unique to Caltech, and provides students with a strong background for future study or work. ACM majors at Caltech may go on to pursue graduate study in applied math or applied sciences, or may pursue careers in industry or finance. Because Caltech's ACM major is, unlike at most universities, divorced from its Math major, we have the unique opportunity to serve the needs of and to educate its students in a manner that is quite focused while maintaining a flexible curriculum.

To this end, we have worked throughout the year to identify areas for improvement in the major and develop proposed solutions. While all aspects of the major were surveyed, this committee opted to focus in particular on modernizing the major with respect to computational / numerical analysis content. We believe that our proposed changes to the ACM program will better prepare its graduates for whatever their future educational or career path may be, while maintaining the flexibility of the program.

2 Issues

The issues in the ACM program addressed by this committee are:

1. The Role of ACM 101 and ACM 106
2. Creation of an ACM 10 "Pizza Course"
3. Increasing Programming Preparedness of ACM Students
4. The Role of Pure Math Courses
5. Research Availability
6. Staffing Shortage

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The sections that follow will deal with each of these issues. In the conclusion of this report, a summary of all recommendations may be found, including the proposed update to the list of option course requirements.

3 The Role of ACM 101 and ACM 106

The course ACM 101abc: Methods of Applied Mathematics I, has long been a mainstay of the ACM curriculum. At the same time, ACM 106abc: Introductory Methods of Computational Mathematics, while not currently a requirement, is regarded by many students and faculty as central to a modern ACM curriculum. It is the belief of this committee that ACM 106 should be incorporated into the course requirements for this option. However, we felt that the flexibility of the major (especially students' ability to choose electives which pertain to their personal career goals and interests) would be heavily compromised if the option required both ACM 101 and ACM 106.

The faculty members responsible for planning the curriculum decided that while ACM 101abc is important, students will gain enough introductory exposure to its content in ACM 95/100abc. ACM 106abc adds a needed breadth of knowledge to the curriculum, containing content which is critical for graduates of Caltech's ACM option to know. We therefore recommended that ACM 101abc be taken out of the requirements, replaced by ACM 106abc. This change has already been set in motion and should take effect in the 2009-2010 course catalog.

There was some concern about student preparedness for ACM 106 with regard to programming background. To this end, we recommend that "ACM 11 or equivalent" be added to the pre-requisite list for ACM 106. It should be further noted that as students may graduate under any course catalog issued during their time at Caltech, the department should be most concerned with ensuring that the class of 2012 and 2013 and beyond are prepared well for programming content in their upper-division courses, as all current ACM students may graduate under the old requirements.

4 Creation of an ACM 10 "Pizza Course"

Several options at Caltech provide a "Pizza Course," a minimal-background seminar course targeted at freshmen. This committee feels that such a course would serve the ACM option well, both in terms of increasing awareness of the types of problems ACM researchers work on for freshmen deciding

between options, and for aiding formation of student-faculty connections which may lead to research opportunities.

It is expected that students will find this course quite valuable. In a survey of current ACM majors, 11 of 25 respondents answered "Yes" to the question, "Would a pizza course have been helpful in your decision to pursue an ACM major?"

As is typical of these courses, the proposed ACM 10 would meet at lunch once a week for one hour and provide pizza to participants. Each seminar would invite one researcher at the Institute who uses methods from applied and computational mathematics in their work. This would include both speakers from the ACM department but also from other departments such as Biology, Mechanical Engineering, etc.

5 Increasing Programming Preparedness of ACM Students

In discussing the importance of computational methods to the ACM major, it became apparent that there is sometimes a disconnect between what faculty expect students are capable of and what students feel is reasonable given their background with regards to programming ability. Faculty on this committee noted that problem sets in ACM courses tend to include problems which require a computational solution when it is appropriate to gaining a full understanding of the content at hand. Still, many ACM majors who were surveyed indicated that they sometimes felt the computational tasks they tend to get on sets can be contrived and/or tedious.

As we move to increase the role of numerical analysis and computational methods in the major, we are mindful of the importance of giving students the right background for their upper-division courses. To this end, the 2007 ACM SFC committee recommended the creation of an ACM 11 course to familiarize students with solving problems computationally in Matlab, Mathematica, and Maple. While the course has met with some success, this committee has a few recommendations to improve its curriculum.

However, student responses to our survey indicate that the crux of the issue is a disconnect between students and faculty on what background is required. Students feel that the importance of programming background is not stressed enough. When they come across problems they do not have sufficient background for, syntax and debugging problems can make sets take much longer than intended.

This committee recommends then that any course which will include

problem sets which require programming background should state "ACM 11 or equivalent" as a pre-requisite. There was some concern that this would make students who already have enough background feel obligated to take ACM 11 when they do not need to. However, we think the wording of this requirement will convey the right message. Further, it seems clear that at this time the catalog is erring greatly on the side of under-informing students of what they are expected to know, so this seems to be an appropriate step in the right direction.

Regarding the content of ACM 11: by now it has been taught twice in two quite different ways. In Fall Term 2007, the content was mostly syntax-focused, covering Matlab, Mathematica, and Maple. In Fall Term 2008, the focus was more on providing an interesting and varied introduction to computational problem-solving. While most who finished the 2008 course reviewed it positively on the TFQR survey, there were complaints that it was under-united, and many students dropped it early in the term.

It is our belief that the 2008 approach is valuable. We recommend increasing the listed units for ACM 11 from 3 units to 6 units. We also recommend to course instructors for ACM 11 that they be mindful of the difficulties in learning syntax and application at the same time: that is, while presenting interesting and challenging computational problems in a set, it should also be taken into account when determining the length of the set that students who are newer to the syntax will take longer to solve each problem even after they understand the main ideas.

6 The Role of Pure Math Courses

The survey of ACM majors we conducted gave insight into many strong opinions about the role of pure math courses in the major. We found that most students are being well served by the Math "menu" of electives. Most students are opting to take Ma 6abc to fulfill this requirement, which we believe is a good course for ACM majors to have (excepting the Ma 6a fiasco of Fall 2007, which was handled with help from the ARC).

The subject of a number of complaints on the survey was the Ma 5abc / Ma 108abc requirement. These courses (Introduction to Abstract Algebra and Classical Analysis, respectively) are intended to develop mathematical reasoning in undergraduates. After an at length discussion about the role of this requirement in the ACM undergraduate curriculum, it was decided that while these courses sometimes prove to be quite difficult, they are an essential part of the curriculum, as the institute has an overriding interest in ensuring

that all ACM graduates are able to reason in a rigorous mathematical way.

There were some suggestions to allow courses like ACM 105 to partially fulfill this requirement. While it is true that as it has been recently taught, ACM 105 provides a level of mathematical rigor appropriate to the requirement, it is not taught consistently enough from year to year to warrant allowing a blanket subsitution. Students who feel that in their special circumstance they should be allowed to substitute a different course for this requirement should talk to the option representative to seek approval.

7 Research Availability

Undergraduates in ACM who are planning further study are often concerned about finding research in ACM. While faculty members are generally happy to have undergraduates research under them, the analytical (as opposed to computational) research most applied math faculty are doing is not easily accessible to the undergraduate background. However, most faculty are able to find numerical research for undergraduates, provided they have sufficient background in computational problem solving.

This committee therefore recommends that advisors of ACM students who are interested in research tell those students to take ACM 95 and ACM 106 as soon as possible. We believe that these courses provide sufficient grounding for a student to be an effective undergraduate researcher. We also suggest updating the recommended course schedule in the catalog along these lines (see concluding section).

It is our hope also that the proposed pizza class will assist undergraduates in discovering labs outside the ACM department that are doing interesting research using ACM techniques, and find research using those connections.

8 Staffing Shortage

The Applied and Computational Mathematics option now contains over fifty undergraduates. As the option continues to grow, students seek increasingly varied and unique course opportunities. Some other options (i.e. Computer Science) offer upper-level seminar courses aimed at exposing students to current research in a certain subfield. It was requested that ACM offer something similar. There was also some discussion within the department of offering an ACM 96 course, which would parallel ACM 95 but contain more in-depth problems and computational techniques. This would be targeted

specifically at ACM majors, since ACM 95 currently serves most of the undergraduate body at Caltech.

These and many other course offerings would improve and diversify the ACM major. However, as of the present time the ACM department simply does not have enough faculty to make these improvements. While securing additional hires may be difficult in the current economic climate, this committee recommends that if undergraduates value these improvements to the diversity and depth of course offerings, they should collectively lobby the administration for additional ACM professors and instructors.

9 Conclusion

This committee believes that the proposed curriculum changes will increase the competitiveness of ACM graduates in their careers or further educational programs. We have attempted to maintain the cherished flexibility of the option and have also proposed a few course improvements. We will continue to work with students and administration to implement these changes. What follows is a summary of our proposals.

9.1 Proposal Summary

What follows is a compact list of all proposals contained in this report:

1. Replace ACM 101abc with ACM 106abc in the course requirements.
2. Create an ACM 10 "Pizza Course" with speakers from ACM as well as speakers from other departments who use ACM methods in their research
3. Add "ACM 11 or equivalent" to the pre-requisites of any course which involves computational problem-solving on its sets, specifically ACM 106, ACM 113, ACM 116, and ACM 118.
4. Increase the unit listing of ACM 11 from 3 to 6. Encourage instructors to focus on presenting interesting problems (not just on syntax), while being mindful of the extra difficulty syntax presents for newcomers to programming.
5. Make no change to the pure math requirements.
6. Have advisors encourage students interested in ACM research to take ACM 95 and ACM 106 as early as possible. Students might also take the pizza course to find useful research connections.

7. ACM majors should collectively lobby for more hirees in the department to increase depth and diversity of course offerings.

9.2 Old Course Requirements

The 2008-2009 course catalog requirements for ACM are listed as follows:

1. Ma 5 abc or Ma 108 abc, and ACM 95 abc, ACM 101 abc, and E 10.
2. An approved sequence of three one-quarter courses to be selected from the following: ACM 104, ACM 105, ACM 106 abc, ACM 113, ACM 116, ACM/ESE 118, ACM 126ab.
3. One of the following (or an approved three-term combination totalling at least 27 units): Ma/CS 6 abc, Ma 109 abc, Ma 110 abc, Ma 120 abc, Ma 121 abc, Ma 122 a, EE/Ma 126 ab, EE/Ma 127 ab, CS/EE/Ma 129 abc, Ma 151 abc.
4. One 27-unit 100 or higher level course in science or engineering not in ACM or Ma and approved by the student's advisor.
5. Passing grades must be obtained in a total of 483 units, including the courses listed above.

9.3 New Course Requirements

The course requirements proposed by this committee are as follows. Please note that we also include a recommendation from the 2007 committee to include ACM 216 and ACM 217 in the ACM elective menu. This committee agrees with that recommendation and would like to see it implemented.

1. Ma 5 abc or Ma 108 abc, and ACM 95 abc, ACM 106 abc, and E 10.
2. An approved sequence of three one-quarter courses to be selected from the following: ACM 101 abc, ACM 104, ACM 105, ACM 113, ACM 116, ACM/ESE 118, ACM 126 ab, ACM 216, ACM 217.
3. One of the following (or an approved three-term combination totalling at least 27 units): Ma/CS 6 abc, Ma 109 abc, Ma 110 abc, Ma 120 abc, Ma 121 abc, Ma 122 a, EE/Ma 126 ab, EE/Ma 127 ab, CS/EE/Ma 129 abc, Ma 151 abc.
4. One 27-unit 100 or higher level course in science or engineering not in ACM or Ma and approved by the student's advisor.

5. Passing grades must be obtained in a total of 483 units, including the courses listed above.

9.4 Old Recommended Course Schedule

Sophomore Year			
Ma 2 ab	9	9	-
Ph 2 ab	9	9	-
Ma 5 abc	9	9	9
HSS Electives	9	9	9
Electives	9	9	27
Total	45	45	45
Junior Year			
ACM 95 abc	12	12	12
HSS Electives	9	9	9
Electives	18	18	18
Total	39	39	39
Senior Year			
ACM 101 abc	9	9	9
HSS Electives	9	9	9
Electives[1]	27	27	27
Total	45	45	45

[1]See items 2 and 3 under option requirements.

9.5 Proposed Recommended Course Schedule

Sophomore Year			
Ma 2 ab	9	9	-
Ph 2 ab	9	9	-
ACM 95 abc	12	12	12
ACM 11	6	-	-
HSS Electives	9	9	9
Electives	-	9	27
Total	45	48	48
Junior Year			
Ma 5 or 108 abc	9	9	9
ACM 106 abc	9	9	9
HSS Electives	9	9	9
Electives[1]	18	18	18
Total	45	45	45
Senior Year			
HSS Electives	9	9	9
Electives[1]	36	27	27
Total	45	36	36

[1]See items 2, 3, and 4 under option requirements.

The main points in the adjustment are as follows. We encourage ACM 95 during sophomore year and a pure math course during junior year, since we believe Ma 5 and Ma 108 require more mathematical maturity than ACM 95. We suggest ACM 11 as a sophomore as well, since it will serve students well in their ACM electives. ACM 101 has been replaced by 106. It has been recommended that 106 be taken in the junior year, so that senior-year ACM and science electives can focus on advanced areas of interest to the student's ambitions for career or further study. Elective units have been updated for a balanced load given the other rearrangements.