A cross-discipline modeling capstone experience

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Institutional background

Gustavus Adolphus College

- selective liberal arts college in rural southern MN
- 2400 undergraduates

Mathematics, Computer Science, and Statistics (MCS) department

- faculty: 2.5 Stats, 3 CS, 6 Math
- 15 - 20 math majors/year; 10 - 15 CS majors/year
- NEW stats major/minor (Spring 2016: 5 majors, 6 minors; Spring 2017: 10 majors, 11 minors)

Course Description

MCS-358: Mathematical Modeling

"This course provides an introductory study of the formulation of mathematical models to represent, predict, and control real-world situations, especially in the social and biological sciences. The course will use ideas from calculus, linear algebra, differential equations, probability, and statistics to describe processes that change in time in some regular manner, which may be deterministic or stochastic.
A mathematical model is a mathematical representation of some physical process or system. Since real-world phenomena are often too complex to model exactly, there are always simplifications and assumptions that one must make in building a mathematical model. In this course we will look at the model-building process and how to critique and refine models."

Course Structure

- capstone course for math & stats majors
- junior or senior standing required
- pre-reqs: calculus sequence, linear algebra, "introduction to proofs", intro CS, intro stats
- enrollment: 17 - 32 students
- co-taught by (applied) mathematician and statistician
- Text: *A Course in Mathematical Modeling* by Mooney and Swift
- January term (4 weeks), even years only
- class time: 2 hours/day; outside-of-class time: ??

Course Topics

1. discrete dynamical systems
2. discrete stochastic models
3. Markov chain models and age-structured models
4. linear and non-linear regression models
5. continuous modeling using ordinary differential equations
6. continuous stochasticity: queuing theory, birth/death processes

Mathematician teaches Chapters 1, 3, 5;
Statistician teaches Chapters 2, 4, 6

Course Focii

- project-based learning
- group work, teamwork, collaboration
- written and oral communication

Course Focus: Project-Based Learning

Chapter Projects:

- 2 days of lecture/classroom activity led by professor M on chapter n,
- 1 day of student presentations from chapter $n-1$ projects,
- 2 days of lecture/classroom activity led by professor S on chapter $n+1$,
- 1 day of student presentations from chapter n projects,
- repeat.

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Term-long Projects: old Mathematical Contest in Modeling (MCM) projects

Course Focus: Group Work

- (almost) no individual work or "homework"
- Chapter projects: randomly(?)-chosen, changing teams of 3-4 students
- Term-long projects: self-selected teams of 3-4 students
- Group self-assessment: 1) questionnaire about group strengths & weaknesses; 2) divide a (hypothetical) honorarium among their group members, based on contributions to the group

Course Focus: Written & Oral Communication

All projects: written and oral report

- Chapter projects: 10-page paper, 15-minute presentation
- Term-long projects: 20-30-page paper, 30-minute presentation

Assessment: rubrics for both written and oral reports

- Written report: abstract, introduction, model description, model assumptions, model analysis, tables and figures, conclusion/discussion, grammar and spelling, citations, and difficulty/extensions.
- Oral report: content knowledge & preparation, content coverage, mechanics (voice quality, pace), time, organization, and slide appearance.

ASA Skills Areas

- Statistical methods and theory
- Data manipulation and computation
- Mathematical foundations
- Statistical practice
- Discipline-specific knowledge

Pedagogical Considerations (from ASA Guidelines)

The approach to teaching this curriculum should model the correct application of statistics:

- Emphasize authentic real-world data and substantive applications related to the statistical analysis cycle
- Develop flexible problem solving skills
- Present problems with a substantive context that is both meaningful to students and true to the motivating research question
- Include experience with statistical computing...
- Encourage synthesis of theory, methods, computation, and applications
- Provide opportunities to work in teams
- Offer frequent opportunities to refine communication skills, tied directly to instruction in technical statistical skills
- Incorporate regular assessment to provide authentic feedback.

Student Feedback: Reported student gains in skills. (2014)

Skills	no gains	little gain	mod. gain	good gain	great gain
Formulating questions, interpreting problems, thinking about existing problems in a more mathematical/algorithmic way	0	0	2	4	10
Writing documents in discipline-appropriate style and format	1	0	0	2	13
Using R	0	1	4	2	9
Oral communication	0	2	3	3	8
Non-oral presentation skills (e.g., making appropriate slides, timing)	0	3	2	4	7
Effectively working in groups	0	0	4	2	10

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- J-term vs. full semester
  - suggestion for a full-semester class: 2 hours/day, 2 days/week
  - afternoon lab/group work? $\longrightarrow$ in-class work days

References

American Statistical Association Undergraduate Guidelines Workgroup (2014), *2014 curriculum guidelines for undergraduate programs in statistical science*, Alexandria, VA: American Statistical Association. http://www.amstat.org/education/curriculumguidelines.cfm

Consortium for Mathematics and Its Applications (COMAP) (2014), "MCM/ICM Contest," http://www.comap.com/undergraduate/contests/.

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Mooney, D. and Swift, R. (1999), *A Course in Mathematical Modeling*, The Mathematical Association of America.

Thank you for your time and attention!
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