Outlines of QES (Quantitative Earth Science) courses – summary of results

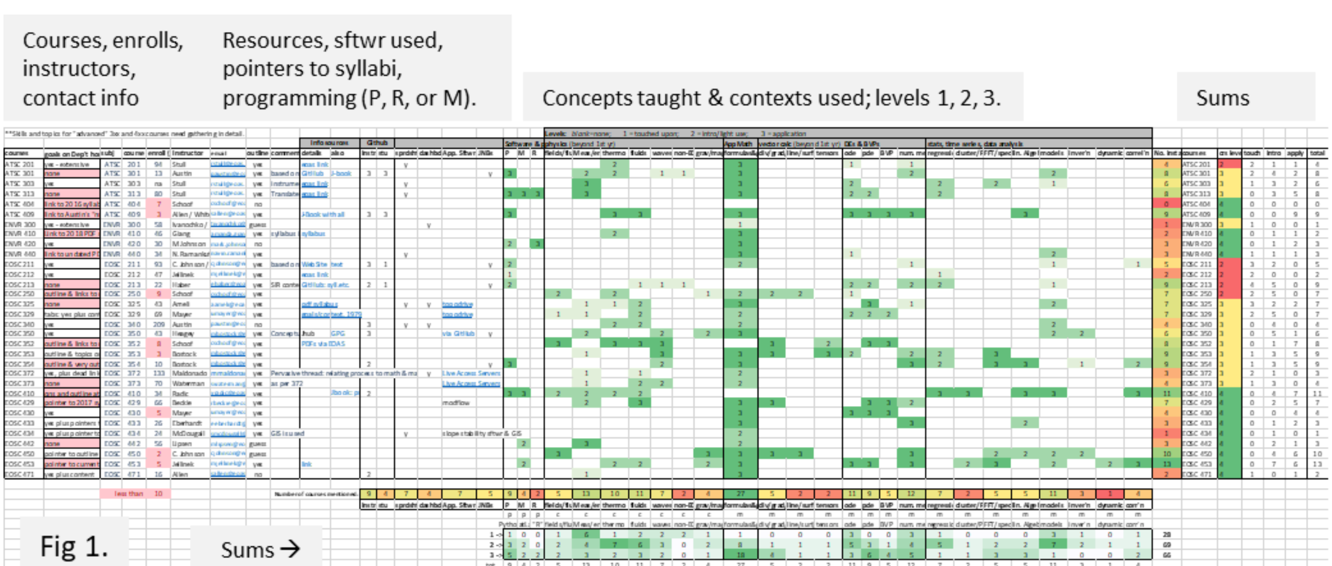
March 2022

Contents

Data gathered

Instructors of 32 courses were asked to complete a Quantitative Course Outline for each course summarizing quantitative concepts learned, and contexts used for that learning. Twenty five forms were returned, 7 were not provided and 3 courses were interpreted or "guessed" based on knowing a bit about them. Courses and instructors are listed in Data Table 1 (last page).

The rest of this summary can be improved by gathering those last few forms, especially since most are 4xx courses. However, the general conclusions will likely not change much.



Results were compiled in the spreadsheet illustrated in Fig 1 (not intended to be readable but provided to illustrate the method). Concepts and contexts were interpreted to have been taught at one of four levels: blank=none; 1 = touched upon; 2 = intro/light use; 3 = application. Concepts and contexts are listed in Data

Table 2 (last page). Note the number of pink cells in column two, indicating courses without course learning outcomes (goals) or other useful information on that course's homepage at the Department's website. Pink cells in column 5 indicate 8 courses with enrollments of fewer than 10 students.

Data quality

Two open ended questions were asked:

1. list the kinds of math, computing or physics **skills** that students learn or apply in that course.
2. add or list corresponding examples used for context or assignments.

Since no specific guidelines were provided, the information returned ranged from cursory to detailed. Some feedback was less about quantitative concepts employed and more about specifics of the subject. Therefore, the rigor or sophistication with which students engaged in the concepts is interpreted here rather loosely.

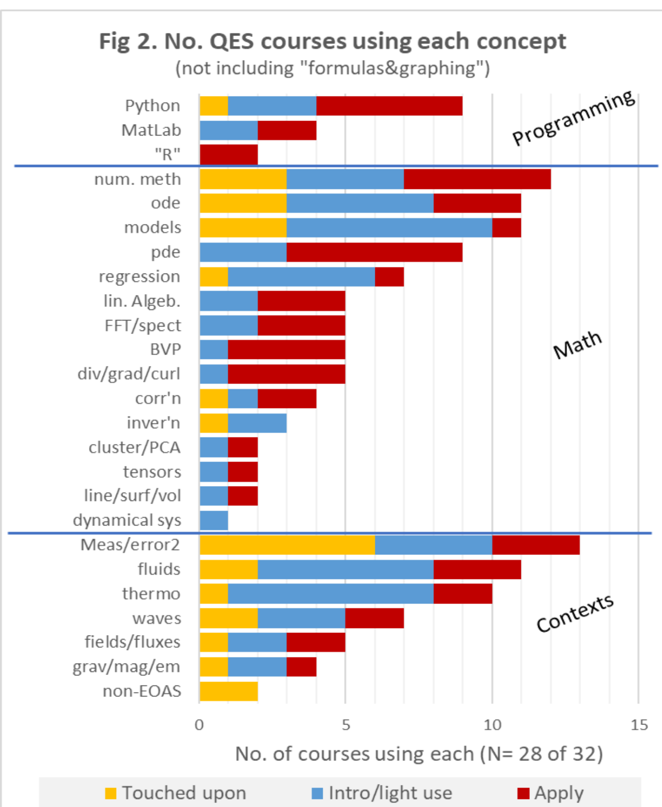
The number of times concepts are either touched upon, used at introductory levels or used in applications varies by course year level roughly as expected; i.e. students get more introductory exposure in 2nd and 3rd year courses and engage in more applications in 4th year courses (figure →).

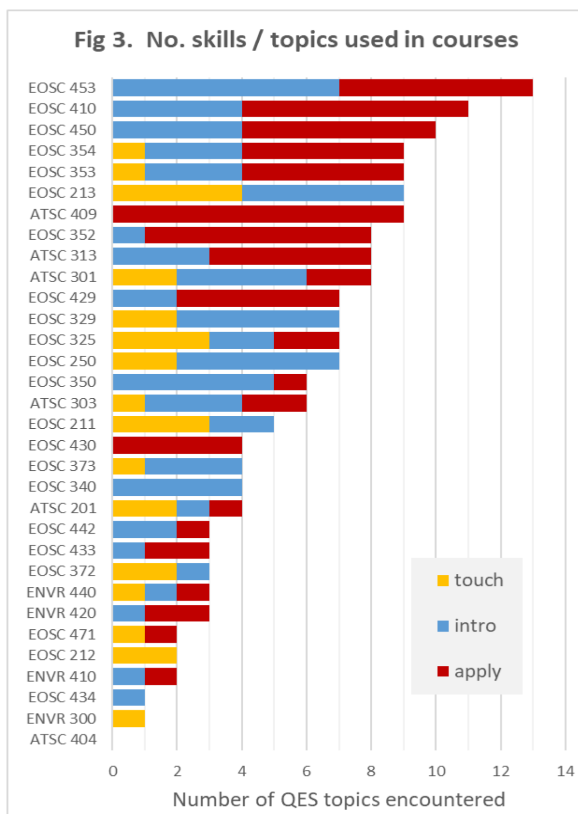
No. occrances of "*touched upon*", "*intro./light usage*" & "*application*" across all 2nd, 3rd or 4th yr courses.

course year	No. courses	touched upon	intro/light use	applic'n
2	5	13	13	1
3	13	10	37	29
4	14	1	20	38
Totals	**32**	**24**	**70**	**68**

Summary of interpreted results

Results should be considered as indicative rather than rigorous. Interpretations will be incomplete because feedback forms were filled out differently in each case. If needed, results could be improved using next steps recommended below.





Figures 2 and 3 summarize results of interpreting the frequency with which students encounter each concept and context. Three bar colours represent counts of interpreted instances of three coverage levels: Yellow = touched upon; blue = intro/light use; red = application. Results are sorted to highlight trends.

Although data quality is variable, the following conclusions are likely general enough to be reasonable.

From Fig. 2:

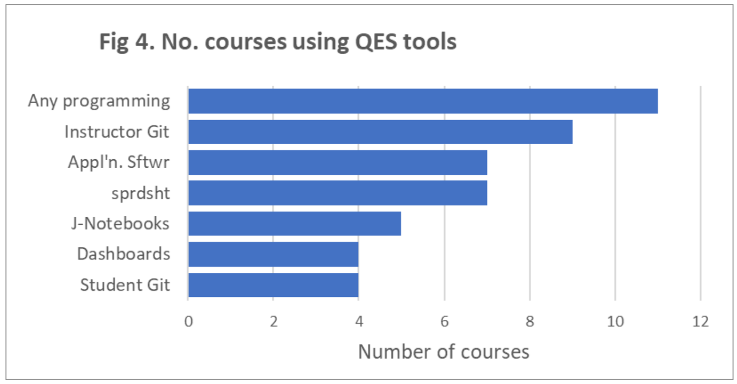
- Python is currently used or allowed in more courses than MatLab or “R”.
- Numerical methods and differential equations are the most used math techniques. Further details would need more targeted discussion with instructors, or detailed syllabi or equivalent.
- Some math concepts overlap (eg numerical methods and differential equations) so further discussion would be helpful.
- The “models” math category is also relatively common but needs further discussion to elucidate.
- Measurements and error are referred to in a range of courses, although the extent to which rigorous measurements practices are involved is not evident from these data.
- Fluids and thermodynamics are most common contexts and probably reflects the greater number of atmospheric and oceanography courses compared to solid earth physics.
- Waves is a context in an “intermediate” number of courses.
- Other geophysical contexts such as potential fields, electrical and electromagnetic processes are less commonly involved.
- “Non-EOAS” contexts include COVID, population or business data etc., e.g. for statistical topics.
- “Geological” contexts such as volcanoes, resources, hydrogeology etc. were not recorded, but those are usually evident by course name. It may be worth incorporating these application settings into a summary of quantitative learning in EOAS.

From Fig. 3:

- Most courses that appear to cover more than 6 topics are 3rd or 4th year courses. Two are 2nd year courses and it is possible that 2nd year courses covering many topics could be overly ambitious. The balance between depth, breadth, rigor and exposure may be worth considering.
- In fact, any course that claims to help students build useful skills across many domains may need consideration to optimize the “breadth” vs “depth”.
- Higher numbers of topics may also indicate there is some overlap in topic names, as mentioned elsewhere.
- The distinction between “touch” and “intro” might be better defined as “intro” (uses the notion briefly), “theory” (background understanding about math/physics is included), and “application” (students apply concepts to problems in assignments or projects). More thought may be required but identifying these distinctions for each course needs a carefully crafted survey or in-person discussions with instructors.

From Fig. 4:

- At least 11 courses appear to have students programming to some extent.
- Instructors in at least 9 courses are using Git for themselves and/or students.
- Use of Jupyter notebooks and dashboards is anticipated to grow between roughly 2021 and 2024.



Recommended next steps

The main goal of characterizing quantitative learning is to generate a complete picture of what students are learning and within which contexts. This will allow the department to (a) agree upon coverage, (b) identify shortcomings or opportunities, (c) point reliably to opportunities open to these students in post-graduation occupations and graduate studies. The following steps would help meet these three goals.

1. Gather syllabi, existing Course Learning Outcomes (CLOs) (learning goals), assignments and exams. (DONE; see QuEST task report 3 "Syllabi-characteristics.xlsx").
2. Use this existing information to build consistent, well-crafted CLOs for every course to fully represent the intended level of exposure to each concept that students can expect. Results will benefit faculty, students, curriculum reviewers, employers, and peer institutions.
3. Use results of this report to establish categories for a survey to enable mapping of QES learning pathways, from theory → practice → application. Include questions about usage, such as: solve on paper; employ math solvers; write code; use of code libraries; prepared tools, etc. Do this online or with interviews. If we get this right and keep it manageable, the survey could be useful to others.

Data tables

Summaries of data obtained and QES (Quantitative Earth Science) concepts interpreted from forms.

TABLE 1. Courses and instructors who were asked to complete a data sheet. "Guess" means FJ estimated coverage based on (admittedly limited) knowledge of the course.

courses	Instructor	outline provided
ATSC 303	Stull	yes
ATSC 313	Stull	yes
ATSC 409	Allen / White	yes
ENVR 410	Giang	yes
ENVR 440	Ramankutty	yes
EOSC 212	Jellinek	yes
EOSC 213	Haber	yes
EOSC 250	Schoof	yes
EOSC 325	Ameli	yes
EOSC 329	Mayer	yes
EOSC 350	Heagey	yes
EOSC 352	Schoof	yes
EOSC 353	Bostock	yes
EOSC 354	Bostock	yes
EOSC 372	Maldonado	yes
EOSC 373	Waterman	yes
EOSC 410	Radic	yes
EOSC 429	Beckie	yes
EOSC 430	Mayer	yes
EOSC 433	Eberhardt	yes
EOSC 434	McDougall	yes
EOSC 453	Jellinek	yes
ATSC 201	Stull	yes
EOSC 442	Lipsen	no
ATSC 404	Schoof	no
ENVR 420	M. Johnson	no
EOSC 340	Austin	no
EOSC 450	C. Johnson	guess
EOSC 471	Allen	no
ENVR 300	Ivanochko	guess
ATSC 301	Austin	guess
EOSC 211	C. Johnson / Austin	guess

TABLE 2. These QES concepts were interpreted to be taught based on data sheets. Each was assessed as being addressed at one of four levels: blank=none; 1 = touched upon; 2 = intro/light use; 3 = application.

Categories	Logged as 1, 2, or 3
Github use	instructor students
Tools	spreadsheets dashboards application sftwr Jupyter notebooks
Software & programming	Python Matlab "R"
physics contexts (beyond 1st yr)	fields / fluxes Measurement or error thermodynamics fluids waves non-Earth science contexts gravity, magnetics or em
Applied math	formulas & graphing
vector calc (beyond 1st yr)	div/grad/curl line/surf/vol integrals tensors
DEs & BVPs	ode's pde's BVP's numerical methods (eg. finite element, volume, etc.)
stats, time series, data analysis	regression cluster / PCA FFT / spectrum linear Algebra models & modelling inversion dynamical systems correlations