EOAS Quantitative Earth Sciences Curriculum Interview Report

Francis Jones, September 2022

Note: This is not meant to be a publication quality report. It is a summary of work done with some inferences drawn from a preliminary analysis of results.

Introduction

Between 2021 and 2023, the UBC Dep't of EOAS[1] has been conducting background research to inform future curricular, course-based and department-wide strategies for improving our quantitative degree specializations, including geophysics, atmospheric sciences, oceanography, and quantitative streams in other specializations. A second goal is to develop strategies for raising awareness of these degree specializations as options that attract students who are keen to learn and apply physics, mathematics and data science in occupations that will address the major challenges facing society.

Part of curricular reform involves establishing how best to balance the learning of discipline-specific fundamentals and the development of "soft" or workplace-related skills. The opportunities available to students upon graduating from rigorous earth-science programs are wide-ranging, and there is often disagreement about what that balance looks like. Therefore, an understanding of current perceptions among EOAS faculty is an important starting point before engaging in discussions that will establish Department-wide priorities.

Towards this end, one-on-one interviews were conducted during summer of 2022 to learn about how EOAS faculty perceive this balance between learning fundamentals and gaining general career-related skills. This report summarizes our methods and results, and offers recommendations based on these insights for steps that could be taken to make these courses, programs and student experiences more inspiring and relevant.

Methods

Twenty six EOAS faculty members were invited to be interviewed about balancing the learning of discipline specific fundamentals versus work-place related skills. During the summer of 2022 we were able complete 20 semi-structured, online interviews of 20-30 minutes each. This sampling of the over 50 faculty members in EOAS was chosen to gain some insights rather than to obtain exhaustive coverage of perceptions. Some characteristics of this sample include:

- 13 interviewees teach courses in the three quantitative science degree specializations; geophysics, atmospheric sciences or oceanography.
- 7 teach courses primarily in environmental, geology or geotechnical disciplines.
- 7 interviewees have either worked in industry or government or their research programs involve industry partnerships.
- 13 interviewees apparently interact professionally only with academically oriented partners (based on personal and professional information at the Department's website).
- 15 research-focused and 5 education-focused faculty participated.
- There were 9 professors, 3 associate professors, 6 assistant professors, 1 lecturer and 1 adjunct professor in the sample group.

[1] The QuEST project (Quantitative Earth Sciences Transformation) is being carried out by UBC's Department of Earth, Ocean and Atmospheric Sciences (EOAS), with support from the UBC "Advancing Educational Renewal" fund.

Questions posed during interviews remained largely consistent for all interviews, with some adjustments based on experience after the first 4-5 interviews. Questions asked were:

1. What is your area of research, and what undergrad courses do you teach?
2. What types of activities or tasks do you have students do in your course(s) that YOU consider to be more about "career preparation" rather than learning about the fundamentals of the discipline?
3. There are two types of careers: academic/research and industry. What aspects of your courses prepare students to work in industry and what aspects of your courses prepare them for academic or research related careers?
4. Have you seen examples or ideas for things you would like to include in your courses that target "soft" or career-related skills?
5. For courses you teach, what would you continue to do that would make you think your courses are successful in preparing your students for future careers?

For each interview, notes were taken in real time and a complete audio recording was kept. Then the audio and notes were reviewed as soon after the interview as practical, to build a cumulative document summarizing both common themes and unique, individual thoughts, opinions and comments.

Results were further interpreted by identifying common perceptions about learning or teaching tactics that target "career preparation". Fourteen themes or tactics aimed at career preparation emerged (Table 1). Counting the number of interviewees who mentioned each tactic provides insights about which tactics are commonly considered important and which are either less important or were not considered.

	Career preparation tactics	**Comments clarifying the meanings of each tactic**
1	Real contexts for problems & projects	"Real" usually meant that real data are used, or problems and concepts are addressed using real research, industry, or community setting contexts.
2	Work with teams and/or peers	Many courses now involve some group, paired or teamwork, either in class, labs or assignments.
3	Communication & writing	Development of oral, written graphical and other communication skills.
4	Focus: field, lab, map, obs'n, etc. skills	Learning for career preparation requires field, laboratory, mapping, observational and other "practical" skills.
5	Focus: physics, math, programming skills	Learning for any career or research pathway should focus on mastery of fundamentals in the basic (usually [physical or mathematical) sciences.
6	Reflective, metacognitive & peer evaluation	Preparing students for their careers requires support that helps them develop abilities to reflect on their work, honestly consider their own thinking, and practicing the giving, receiving and effective use of peer evaluations.
7	Emulate professional tasks	Labs, assignments or projects are designed to look and feel like a "normal" professional task, such as responding to a request for proposal, focusing on a "client's" needs, etc.
8	Economics, safety, regulations, gov't. etc.	Courses should include some introduction to the non-academic aspects of the "world of work", such as BC laws, rules and policies, "how the government works", and economic aspects of a problem or project.
9	Networking & professional contacts	Degree programs should foster opportunities for students to meet and connect with job-related people and organizations.
10	Guest contributors	Bringing in guests to contribute to a course is a beneficial career-preparation tactic.
11	Industry & academic needs are similar	Skills and attitudes students must develop are similar regardless of whether students pursue careers or research-based graduate degrees upon graduation.
12	Critical, scientific, & precise thinking	Career preparation requires development of thinking abilities that are critical, logical scientific and precise.
13	Offer work experiences	Degree programs should foster opportunities for students to work outside the academic setting.

14	Dep't & other social events	Social events should be fostered, enabling students to gather with peers, instructors and potential employers or colleagues.

Table 1: Career preparation tactics emerging from interviews.

Results

Results are presented first in aggregate form to illustrate the degree of consensus among interviewees. Some thoughts from individuals are summarized after discussion of aggregate results.

Aggregate results

Figure 1 illustrates which tactics the interviewees mentioned as currently in use in the courses they teach. Sorting in order from most to least commonly mentioned helps visualize the extent of common perceptions among this group of interviewees.

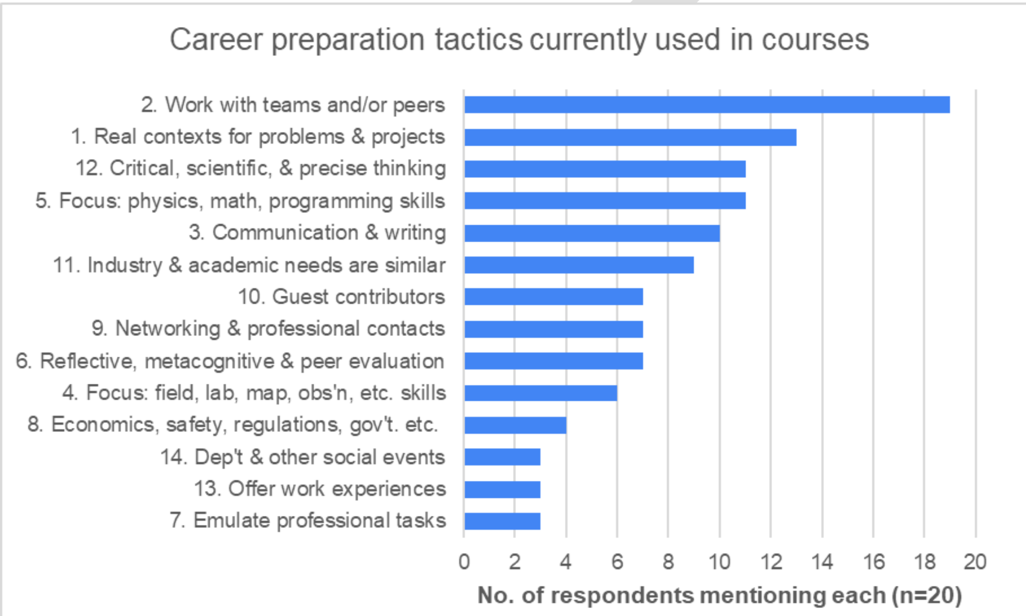

Figure 1: *Summarizing the number of respondents who mentioned they use each career-preparation tactic in their courses. Numbered tactics correspond to Table 1.*

Figure 2 compares aggregate responses from two groups of faculty. Individuals were placed in one or the other group based on CVs and research project descriptions at the EOAS website. The two groups include:

a) Faculty members who have industry or government work experience or research partners (n=7);
b) Faculty members who have purely academic backgrounds and research contexts (n=13).

In Figure 2, the frequency with which each tactic was mentioned is shown as a proportion of these two sample subsets. Unlike Figure 1, tactics that are "*currently in use*" and those that faculty "*would like to use more if time and circumstances permitted*" are combined.

Figure 3 is similar to Figure 2 but compares aggregate responses from a different two groups of faculty:

a) those who teach geophysics, atmospheric sciences and oceanography courses (n=13);
b) those who teach environmental, geological and geotechnical courses (n=7).

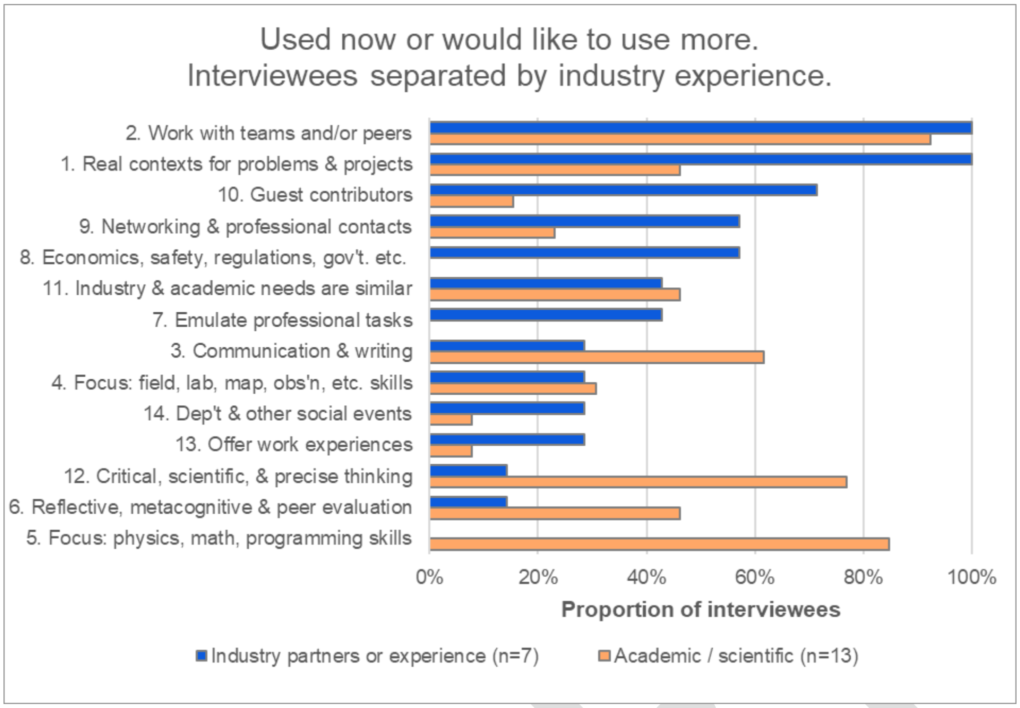

Figure 2: *Comparing interviewees with industry experiences against those with primarily academic experience. Proportions of each group are used to illustrate the extent of agreement among interviewees in each group. Results should be considered generally as no significance tests have been applied. Numbered tactics correspond to Table 1.*

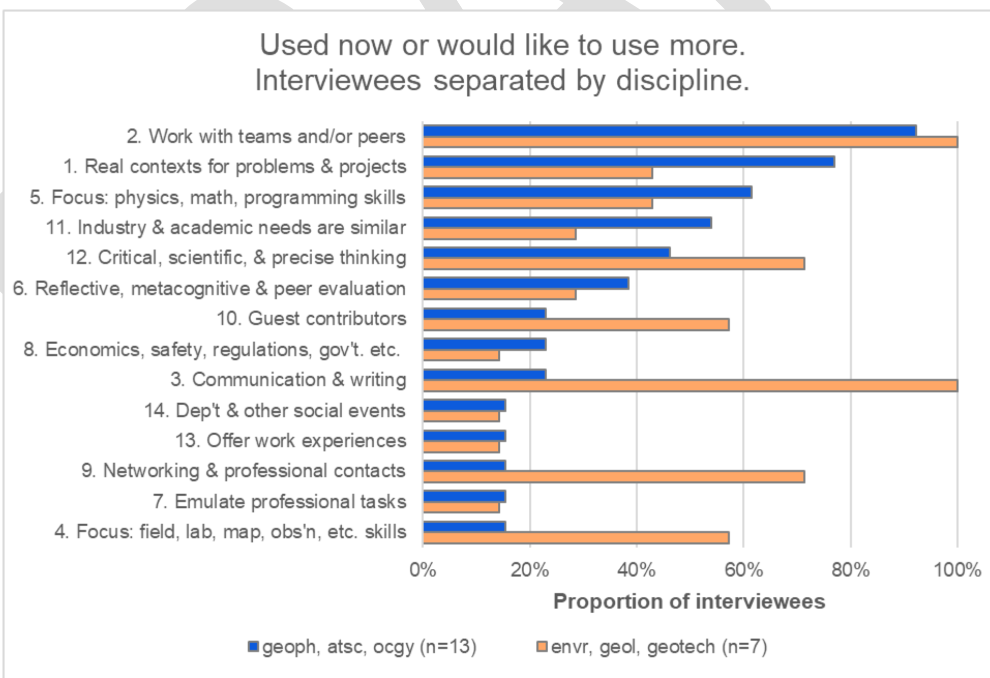

Figure 3: *Comparing interviewees who teach courses in the quantitative disciplines (geophysics, atmospheric sciences & oceanography) against those teaching in environmental, geological or geotechnical disciplines. Numbered tactics correspond to Table 1.*

Discussion of aggregate results

Career preparation in current courses

From **Figure 1**, the tactic "*having students work in teams, groups or pairs*" was the only tactic identified as currently in use by the majority of interviewees. This is certainly good to see as the ability to work effectively with others is expected in any post-graduation situation. See the selected individual comments and suggestions below for further remarks related to benefits of learning in teams and groups.

"*Employing real contexts*" was mentioned by only 13 of 20 interviewees. This tactic is one that could be improved relatively efficiently, perhaps with educational development support to find suitable data sets or "real world" problem situations consistent with existing learning objectives of a course. An example of current initiatives of this type includes the various incentives available to UBC faculty to incorporate climate science into their courses.

A similar tactic, "*emulating professional tasks*", was mentioned as in use by only 3 interviewees. This number may be small since it is somewhat similar to "*employing real contexts*". However, it should be relatively easy to ensure that at least some of the "real contexts" are designed so that students gain some appreciation for how professionals work.

The remaining tactics aimed at career preparation were each identified by fewer than 11 or fewer of the 20 respondents. This low usage of career-preparation tactics suggests there may be room for instructors to learn how to creatively weave corresponding learning opportunities into existing courses, without changing primary objectives. UBC does have experts in the Centre for Student Involvement and Careers (CSIC) who can provide coaching, workshops, seminars or other opportunities to help.

Communication or writing skills are used by only half the interviewees, although discussions suggested that this is still considered very important. The barrier is most likely a limited capacity to assess written or presentation work in courses with larger enrollments. Gaining those skills could be focused to a few courses, however, building writing and communications skills is not something that happens quickly. Consistency and repetition are important, and there should perhaps be opportunities to practice these capabilities throughout the curriculum.

Comparing industry-informed and academic perspectives

Figure 2 compares responses of interviewees with industry experiences against those with primarily academic experience. The number of individuals in each group is small, and no statistics have been applied to establish significance, however several observations seem to be interesting.

1. Faculty with industry experience mentioned the following as important aspects of career preparation more consistently than faculty with no industry experience or connections:
    a. incorporating real contexts into problems and projects;
    b. bringing guest contributors to class;
    c. supporting opportunities for students to network with professionals;
    d. teaching economic, safety, regulations and other aspects of the workplace;
    e. emulating professional tasks in assignments.
    f. Supporting social events and offering work experiences.
2. Faculty with primarily academic perspectives mentioned the following as important aspects of career preparation more consistently than faculty with connections to industry:
    a. communication & writing skills;
    b. critical and scientific thinking;
    c. opportunities to develop reflective & metacognitive skills;
    d. the need to focus on "fundamentals" like physics and math.

3. Tactics considered roughly equally important by both groups include:
    a. team/group work;
    b. the notion that preparing for academic or industry careers are largely similar;
    c. focus on field, lab, observational, etc. skills.

Note that 85% of "academic" faculty mentioned "*Focus on physics, math and programming skills*" as an important aspect of career preparation while none of the faculty with industry experience mentioned this during interviews. Of course, that does not mean those faculty consider learning about fundamentals as unimportant. But it may suggest that they have a different perception of the distinction between "*learning fundamentals*" and learning that specifically targets "*career preparation*".

Comparing perspectives of those teaching quantitative versus other courses

Figure 3 compares responses of interviewees who teach in the geophysics, atmospheric sciences, or oceanography disciplines to those teaching in environmental, geological or geotechnical disciplines. Observations that seem interesting include:

1. Responses of these two groups are more consistent than groupings used for Figure 2. This suggests that perspectives about career-preparation are less dependent upon the disciplines than on whether instructors have experienced working for, or working with, the non-academic sectors.
2. Exceptions appear to be that those teaching the less quantitative courses appear to use or want to use these 5 tactics more than their colleagues who teach quantitative courses:
    a. Communication & writing skills;
    b. Networking and professional contacts;
    c. Focus on field, lab, mapping and observational skills;
    d. guest contributors;
    e. (possibly) critical scientific & precise thinking.
3. Those teaching in the more quantitatively focused disciplines may be more inclined to use or want to use the following, although these differences appear less significant than those mentioned above.
    a. Use of real contexts for problems and projects;
    b. Focus on physics, math, programming;
    c. Consider industry and academic needs to be similar.

Individual comments or suggestions

As with any set of interviews, individuals had unique and sometimes insightful thoughts or suggestions. Here are a selected few, without mentioning who made them, and presented in a random order. These organized into 'themes' and are paraphrased rather than direct quotes.

- **Teams:** Group work supports development of networking skills, helps students reinforce their learning, increases their confidence with asking questions of peers, supports critical evaluation of various approaches or procedures, and reveals alternative solutions. Gaining the confidence to share work with peers and ask questions is an essential asset that will help students thrive in the workforce.
- **Course structures that balance fundamentals and career preparation**:
    - Start a course by addressing fundamentals, then focus on applications later in the course.
    - In courses with labs, lectures tend to cover fundamentals while labs involve application of new knowledge and development or practice of skills.
    - Front load fundamentals and transition to application at the end of the course. (Ed. note: this is "**bottom up**" learning. "**Top down**" learning involves introducing purposes first, then addressing fundamentals "*as needed*". The pros and cons of each are frequently debated.)
- **First year math/physics:** Students who are interested in physics, math and data science should have more focused and specific first year courses. Related thoughts include:

- First year courses are too descriptive. Instead, they should become more quantitative and qualitative (Ed. Note: we are not clear if this interviewee was referring to 1st yr EOAS or first year math.)
- Students need to encounter problems that involve statistics, time series analysis, mapping and solving differential equations.
- Students say: "*the math courses that I took in first year did not prepare me for the math I learned or used in atmospheric sciences & geophysics.*"

- **Math in EOAS courses:** Add more math content into the courses taught in EOAS (derivatives, how to plot slopes, calculus, differential equations). Related thoughts include:
  - Teach students how to plot without using a program like excel.
  - Teach more sophisticated uses of spreadsheets because that's the tool they'll be using most.
- **Writing:** students need to learn how to write for science and technology, not literature.
- **Portfolios:** Build a 4 year portfolio to help students (a) develop their professional identity and (b) gather evidence of their learning and accomplishments for their career-search efforts.
- **Giving and receiving feedback**: Provide more opportunities for constructive peer interactions. Peer review also allows students to see how other people approach the same question and learn something new.
- **Meaningful, relevant contexts:**
  - Teach *relatable* topics to students so that they would want to take those courses. For example, more high school students are interested in climate change.
  - Frequently share current business, industry or social news & developments that are relevant to the subjects.
- **Social & professional networking events**:
  - Facilitate opportunities for more students to experience the local Vancouver "Roundup" mineral industry conference or other similar professional events. This would enable students to meet alumni, recent graduates and other industry personnel and to experience first-hand the attitudes, priorities and concerns of professionals.
  - A departmental social coordinator could help encourage and host social and networking events. Clubs are important, but not every year do they have a well-organized group of executives. Students also benefit from assistance with finding and contacting possible contributors.
- **Supporting under-achievers:** Invite students who did not do so well on their midterm to talk to the professor and TAs after class for a study session. (Ed. note: see research done partly in our Department, in Deslauriers, Harris, Lane and Wieman, 2012 "*Transforming the Lowest-Performing Students: An Intervention That Worked*".)
- **Consistency:** Development of maturity, knowledge and skills needs to be more consistent year-to-year. Eg:
  - Math, physics and applied aspects are missing in the second year courses.
  - Need math and physics courses in first year that are more specific and less "theoretical".

Recommendations

First, the 14 "tactics" that have emerged from these interviews will become part of a brief survey aimed at learning about perceptions of all EOAS faculty.

Specific inferences (as opposed to "conclusions") that seem well-supported by these interview results include the following:

1. Tactics that support industry and academic career development certainly overlap. But there are distinctions. "Soft" or "work-related" skills that employers want, and those expected by graduate schools, need to be clarified and incorporated clearly and equitably into the curriculum.
2. Learning in teams, groups and with peers is evidently common now in EOAS. This in excellent agreement with current wisdom about teaching and learning best practices: Learning to become an effective professional is not a solitary activity. But students need to be made aware of, and appreciate why, especially in first and second year.
3. Incorporating real and meaningful contexts into learning about new concepts and skills improves motivation & retention and helps bridge that challenging gab between theory and application.

Contexts should include those a new graduate might expect when entering a profession. Incorporating regulations, safety, and economic aspects of these contexts is also highly recommended, even if only briefly.

4. Three key aspects of learning that involve long term growth and maturity are (a) development of critical, scientific and precise thinking; (b) oral, written and graph-based communication of ideas or knowledge; and (c) reflective, metacognitive abilities including the ability to give and receive constructive criticism with colleagues. Year-by-year consistency & continuity is important and requires department-wide efforts to identify how development of these abilities is threaded throughout a degree's curriculum.
5. Guest contributors are well received especially if students have a chance to mingle with the guest and learn about their work informally. For example, UBC's Science 1 program includes an informal meet-and-greet lunch following a guest's contribution.
6. The department could be more proactive in supporting social and professional networking events. Clubs can take the lead, but they are, after all, "beginners" in the relevant disciplines and professions and do yet not have a professional network of contacts.

More specific recommendations could be articulated from these interviews, but that step will be more appropriate in the QuEST project's final reports.