QuEST – EOAS Quantitative Earth Science Transformation project

Recommendations for reinvigorating quantitative learning in Earth, Ocean and Atmospheric Sciences

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Francis Jones, January 2024, UBC Dep't Earth, Ocean and Atmospheric Sciences[1]

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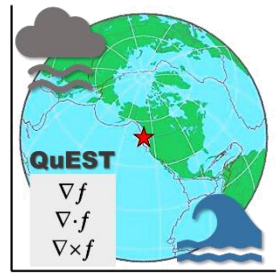
Contents

1 EXECUTIVE SUMMARY

This executive summary's sections are: (1) **Background**, (2) **Recommendations** and (3) **Comments on the nature of change**. Raw data, working datasets and all other project materials, including presentations, are on the EOAS NextDrive Cloud server accessible only to those with an EOAS account.

Project goals: The "*Quantitative Earth Sciences Transformation*" (QuEST) project's goals were to **…**



1) Characterize current **quantitative Earth Science** (**QES**) offerings across the EOAS undergraduate curriculum (QES is defined under "scope");
2) Recommend strategies for rejuvenating these undergraduate degree specializations to align more closely with the rapidly evolving research priorities and employment opportunities
3) Explore and initiate **marketing strategies** that will inspire and attract appropriate students to pursue their undergraduate qualifications that will be rigorous, relevant and rewarding in a wide range of potential career or further educational opportunities.

1. BACKGROUND

Scope: At UBC the quantitative Earth science degree specializations include **geophysics**, **atmospheric sciences**, and **physical oceanography**, and QuEST recommendations primarily focus on these three disciplines or areas where they intersect. The **environmental science** program is also interested in enabling students to pursue a more quantitative focus. **Geology** faculty also recognize quantitative thinking skills as increasingly important for practitioners and researchers. While these programs are not specifically targeted in QuEST recommendations, many ideas presented here could be applied in their courses or curricula, perhaps with adjustments to suite different contexts. Finally, the **geological engineering** program, although certainly a quantitative discipline, is also not a primary focus for the QuEST project as it the constraints and priorities of BASc programs differ from those of BSc degrees.

Activity: With funding from UBC's Advancing Education Renewal Fund and Departmental support, work was carried out between spring 2020 and end of 2023. This coincided with the COVID pandemic limiting opportunities to engage with individuals both directly and indirectly. As is well known, everyone's capacity to engage in new activities was severely limited, other than the effort to "pivot" to the online world for teaching and research.

Never-the-less, surveys, interviews, consultations with educational experts at UBC and beyond, participation in geoscience education workshops, and background literature research were all carried out. Two professors provided faculty oversight, and work was mostly done by an EOAS lecturer and educational developer (half time), and one hired summer student, with generous contributions of time and expertise from CTLT (C. Hunter) and UBC Career Services (K. Rawes). The project's timeline is summarized on the methods page.

Nineteen quantitative and qualitative **data sets** or **reports** were gathered, analyzed or prepared with results listed in tables of data sets and reports. Summaries of several **faculty discussions** are also on that page. **Tools or resources** built to support QuEST activities, future curriculum work or for student support are summarized with links on the tools and resources page. Many **sources** were used, and the 87 references actually cited are included on a references page, including some web resources. **Complete reports** and **discussion papers** that are referenced or summarized elsewhere are included as twelve appendices. Finally, contributions about QuEST work within UBC and at external conferences are listed on the references page.

Frameworks: Characterizing current curriculum and generating practical recommendations for rejuvenating degree programs is best done using frameworks based on precedent and well respected educational practices. These include: • UBC-wide program renewal guidelines, • experiences from other institutions, • practical guidelines for specific tasks such as designing Program Learning Objectives, • perspectives such as "transparency of teaching practice" and • "emphasis on authentic learning", • a persistent student-centric point of view, and • career-development priorities — all these and others are part of underlying precedent and wisdom that has informed QuEST's review work and the preparation of recommendations. See the frameworks page for details.

Current State: To provide background and context, the "Currently" portion of QuEST documentation describes and discusses the following:

- Current degrees offered & courses taught in EOAS;
- The global nature of geoscience student enrollments and societal demand for geoscientist;
- A detailed assessment of skills students need to succeed;
- A summary of Departmental discussions about QES curriculum prior to the QuEST project.

Data characterizing the quantitative learning that students encounter in EOAS suggest that students are certainly gaining significant expertise in mathematics, physics of Earth processes, and computing. However, some courses have not evolved much in a decade or more. It also seems that courses are to some degree "isolated". The progressive development of capabilities that students experience from year to year could be made clearer, with earlier courses being more transparent about how skills being learned will be important later, and senior courses being more explicit and transparent about building upon skills and knowledge from earlier courses.

Desirable skills: There is an extensive report discussing the knowledge, attitudes, skills and habits that students should be developing as geoscience undergraduates, to best serve their needs and those of society. The discussion is based on internal conversations and the perspectives from the wider academic and non-academic communities. The opinions of EOAS faculty and those of the wider community (including non-academic sectors) are largely consistent, although employers tend to look more for "personal maturity" and "readiness to work" while research faculty tend to focus on discipline-specific knowledge and skills.

Curriculum: An overarching theme emerging from QuEST work is the need to deliver quantitative BSc programs that balance three diverse objectives: students need to develop:

- level-appropriate capabilities to think and problem-solve using mathematical, physical and computational concepts that are fundamental to Earth sciences and the analysis of corresponding data;
- "soft" or "work-related" skills and attitudes to ensure they can successfully compete for employment (desired by roughly 80% of EOAS students) or graduate positions;
- life-long learning abilities and attitudes to leverage the rapidly advancing techniques and technologies emerging now and in years to come.

Radical change to curriculum, content, and delivery is interesting (and considered) but it is by no means the only option. See "the nature of change" below. Instead it may be easier to consider "gentle" evolution of existing degree specializations by:

- adjusting the priorities, content, and pedagogies of individual courses so that learning is inspiring, relevant, active and focused on students' current and future needs;
- ensuring that senior courses are making effective use of early course;
- incorporating both career preparation and development of age-appropriate maturity with respect to fundamental quantitative concepts and applications;
- balancing the depth and breadth of learning that a degree from a premier research institution should provide.

It is also recognized within the Department, and more broadly by UBC and at peer institutions, that an equally important aspect of curriculum renewal is enhancing and maintaining a greater sense of community among QES students, graduate students, faculty and corresponding employment sectors.

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2. RESULTING RECOMMENDATIONS

The roughly 150 specific suggested actions or recommendations are organized into 21 categories.

> **All are listed on one page at the project's Blog site** and duplicated in this report, ***Ch. 4.2, Recommendations outline***.

> The recommendation categories **are summarized in a single table (below)** in terms of type, implementation context and urgency, impactfulness and cost.

Recommendations range from the straight forward (such as rationalizing syllabi for consistency and transparency) to the complex and perhaps even "radical" (such as re-configuring whole degree specializations). Recommendations are organized by the context in which they would be implemented, including:

- adjustments that could be made within courses;
- enhancements to existing degrees;
- changes to degree programs requiring greater commitment and approval;
- administrative or "cultural" adjustments at the departmental level;
- improvements to student academic and community support, especially regarding career preparation.

How are recommendations expected to be used? It is certainly true that curriculum belongs to the faculty. Understandably, curricula are often geared towards specific disciplinary goals, and change can be hard even if it is desired. There may even be cynicism since curriculum reform is sometimes based on fads and box-checking rather than genuine engagement (Usher, 2018). Therefore it is anticipated that an important "next step" will be to use recommendations to help clarify priorities among stake holders, using them as a starting point for discussions to clarify goals. Then a "project" can be initiated, practical plans and timelines can be prepared, and support can be sought as needed.

Marketing; Attracting students into QES degree specializations is a priority and activities were under way before the QuEST project began. Development of a new first year course specifically for students with quantitative interests has been discussed since before QuEST. Progress stalled during COVID, but there is a page of QuEST reporting devoted to recommendations regarding a first year quantitatively oriented course, including development tactics, choices of content, and how to teach it. Departmental perspectives at the time discussions stalled (mid-late 2020) are also summarized on that page.

QuEST project recommendations

Date: Friday, December 8, 2023

			Recommendation types**						implementation context				ratings (low - high = 1 - 3)			
No.	**Recommended curricular renewal or marketing objectives***	**No. items**	**1**	**2**	**3**	**4**	**5**	**6**	**course or crs set**	**degree**	**dep't**	**marketing**	**urgency**	**impactful**	**cost of implem't**	**cost of sustaining**
TARGET: ENHANCING COURSES																
1	Rejuvenate syllabi and CLOs	4			✓	✓	✓		✓				3	3	1	1
2	Enhance QES learning by focusing on "quantitative critical thinking"	11		✓			✓		✓				2	2	1	1
3	Increase use of applications and context	3		✓	✓	✓	✓	✓	✓				2	2	1	1
4	Quantitative concepts in service courses.	7		✓		✓			✓		✓		2	2	2	1
TARGET: EXISTING DEGREES																
5	Revitalize degree priorities and corresponding PLOs	6			✓	✓	✓			✓			3	2	1	1
6	Enhance delivery of existing degree programs	5	✓	✓	✓	✓	✓	✓		✓			2	3	3	1
TARGET: ADJUSTING DEGREE PROGRAMS																
7	Adjusting current degree programs	4	✓	✓	✓		✓	✓		✓			2	3	2	2
8	Alternative perspectives on a QES degree	6	✓	✓	✓	✓		✓		✓	✓		1	3	3	3
TARGET: IDEAS AT THE DEP'T LEVEL																
9	Enhance and streamline faculty & TA support and development	6						✓			✓		1	2	2	2
TARGET: STUDENT SUPPORT																
10	Increase students' sense of community within EOAS & QES3	3				✓	✓	✓			✓		3	2	1	1
11	Improve the efficiency and efficacy of QES program advising	6			✓		✓	✓		✓	✓		3	3	2	2
TARGET: CAREER PREPARATION																
12	Incorporate career-related settings into learning activities and tasks	9		✓	✓		✓		✓			✓	3	3	1	1
13	Improve the support for professional registration.	6			✓		✓			✓	✓		3	2	1	1
TARGET: MARKETING QES																
14	A quantitative EOAS first year course	19		✓		✓			✓			✓	2	2	3	2
15	Establish a sustainable marketing strategy.	8				✓		✓			✓	✓	3	3	2	2
16	Attract BSc students as they choose their degree specialization.	6				✓		✓			✓	✓	3	3	1	1
17	Showcase things students learn and experience	8				✓	✓	✓			✓	✓	3	2	1	1
18	Foster partnerships emphasizing QES	11		✓	✓	✓		✓	✓		✓	✓	2	2	2	2
19	Engage in active outreach to high schools and Vantage	6				✓						✓	2	2	2	2
20	Alumni engagement	6			✓		✓	✓			✓	✓	2	3	2	1
21	Enhance EOAS website content for QES recruiting	9				✓	✓				✓	✓	3	3	1	1

***Recommended curricular renewal or marketing objectives or "aspirations"**

For each recommended **objective** see corresponding recommended **actions** at --> https://blogs.ubc.ca/eoasquest/

****Types of recommendations emerging from QuEST project work**

1 Establish new approaches to inter-disciplinary QES education across the Earth sciences.
2 Enhance the depth, breadth or relevance of quantitative learning .
3 Support career awareness and preparation for existing students.
4 Attract appropriate students into QES degrees.
5 Inspire / motivate enrolled students regarding quantitative aspects of Earth sciences.
6 Foster a dep't culture of more efficient & effective engagement with undergraduates.

Other initiatives started during QuEST are listed in table form with pointers to details. These include

- Build a prototype for a Canvas-based resource to support advising for all EOAS undergraduates.
- Initiate guest partnerships between EOAS faculty and the Math department to introduce climate science as a context for first mathematics courses.
- Clarify EGBC requirements for geophysics students (awaiting approval from EGBC, probably early 2024).
- Gather ideas and guidelines for incorporating as seamlessly as possible aspects of career preparation into existing courses.
- Adjustments to the EOAS and UBC websites making quantitative Earth science degrees and corresponding career prospects more visible and inspiring to students.

There are seven other categories of recommendations for actions aimed at raising the visibility and attractiveness of EOAS as a place to pursue rigorous, rewarding and valued quantitative and data-oriented degrees.

- Establish a sustainable Departmental marketing strategy specifically for inspiration and recruiting, as distinct from (although perhaps overlapping with) public outreach. (8 specific suggestions)
- Attract BSc students at the time they choose their degree specialization. (6 specific suggestions)
- Showcase the inspiring things students learn and experience so that prospective students can see and understand the values and rewards of QES degrees. (8 specific suggestions)
- Foster partnerships both within and beyond UBC, emphasizing QES courses, degrees and degree-options. (11 specific suggestions)
- Engage in active outreach to high schools and Vantage. (6 specific suggestions)
- Alumni engagement specifically for providing examples of how QES degree qualifications are used in valuable and rewarding post-graduation opportunities. (6 specific suggestions)
- Enhance EOAS (and UBC) website content that targets QES recruiting. (9 specific suggestions)

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3. COMMENTS ON THE NATURE OF CHANGE

Traditionally, the important variables in education have been considered to be related to content, curriculum, or pedagogy. This is a common perspective of experts in any field when they take on the responsibility of educating the next generation of professionals. This not "wrong" but arguably not complete. UBC Faculty of Science learned during the Carl Weiman initiative between 2007 and 2013 (and continues to learn) that change at any level is less about the material or practices, and more about both the *academic culture* of the unit (research group, department, faculty – etc.) and the "*emotional nature of the process of change*". To quote Goldberg and Somerville, 2015 (their context is engineering but the point is entirely relevant in science contexts):

"… we needed to admit that the secret sauce to … [educational reform] … was profoundly emotional in nature and that words like "trust," "courage," "joy," "connection," and "openness" (the five pillars of transformation) were necessary to convey and understand the experience. And this was excruciatingly hard for a couple of engineers to understand and embrace, but once we did, we knew there was no going back. A particular simplified formulation we like is that
"Authentic transformation leads to an unleashing of students", and that
Unleashing = Trust –> Courage –> Initiative –> Failure –> Authentic learning*"*

Using more "formal" research methods, Shadle et al., 2017 identified **15 "drivers" that motivate faculty** to participate in post-secondary STEM education reform and **18 "barriers" that reduce the likelihood of success**. Their results are summarized in two charts, and not surprisingly, both the **favorable conditions** and the **challenges** are mostly "soft" rather than discipline-specific. Also not surprisingly, "time" is by far the most commonly mentioned barrier to change – but **time** is a fixed commodity so this translates into "**priority**". Everyone has the same amount of time – it's mainly a matter of what you value or how you choose to spend your time.

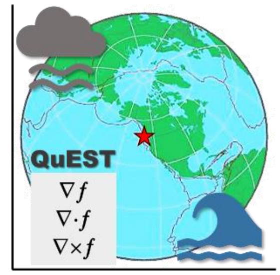
The point is that we can make any number of seemingly practical suggestions to change courses, course sequences, a degree program or even departmental practices for supporting students. BUT – success will be much more likely (and complete) when all those involved arrive at a state of trust, recognize the courage needed, act to initiate and sustain the changes agreed upon, "fail" gracefully by learning from the experience and moving forward, and strive for "authentic student learning" that goes beyond the confines of an individual's (or group's) expertise by facilitating development of knowledge, skills and attitudes that STUDENTS will need in any of their myriad of post-graduation options.

Hopefully the results and recommendations arising from the QuEST project will serve as a starting point to clarify, then agree upon priorities, to trust all colleagues and stakeholders, and to initiate (with sufficient resources) changes that will ensure the quantitative Earth science degrees will grow, thrive and set a global standard for excellence and relevance for the coming generations of geoscientists – expertise the world needs urgently.

Finally – some thoughts are provided separately regarding "**next steps**" to follow up after the QuEST project results have been reviewed. See the next steps page.

2 INTRODUCTORY MATERIAL

2.1 PROJECT INSPIRATION



Societal urgency, from the proposal: "…*modern Earth sciences have changed significantly over the past quarter century, with a much greater emphasis on collaboration across fields, and the deployment of core mathematical and computational techniques to solve complex problems from a range of perspectives. The next generation of students – those who will be responsible for tackling the climate crisis and for developing sustainable resource exploration industries – will need to apply their education much more broadly than ever before."*

Visibility / awareness of opportunity: The Earth, ocean, atmospheric, climate and environmental disciplines provide an inspiring and meaningful context for developing both fundamental and applied mathematics, physics and computing knowledge and capabilities. Yet many prospective students and their families are unaware of the potential for rewarding and impactful occupations and the growing need for quantitatively oriented professionals in these fields. Therefore there is a need for "marketing" the disciplines and showcasing the inspiring & rewarding opportunities for studying and practising in these professions.

Timely and ready: UBC's Department of Earth, Ocean and Atmospheric Sciences has a uniquely diverse range of research interests, degree programs and courses. We also have a history of leadership in science (especially geoscience) education innovation and development. Therefore, we are currently well suited to pursue a re-envisioning of how quantitative subjects are taught and learned, from individual innovations in specific courses to Department-wide curricular initiatives.

The executive summary of the Department's **strategic plan,** ***EOAS 2021: A Vision for Integrated Earth Science*** (P. Tortell, Dec 7, 2021) articulates the vision that the QuEST project supports. It states that the Department aims to "*… expand the use of quantitative and open-source computational methods to address a range of Earth Science questions through advanced data analysis and modelling methods."*

2.2 OBJECTIVES

From the proposal: "… *we seek to critically evaluate current* ***Quantitative Earth Science*** (**QES**) *offerings across the EOAS undergraduate curriculum, creating a road map to rejuvenate multiple specializations, while forging a new approach to inter-disciplinary education across the Earth sciences. We seek to re-align our undergraduate specializations with the rapidly shifting landscape of Earth Science research, and the corresponding changing employment market.* "

Also "… *we will develop market research strategies to learn how students make degree choice decisions, and how renewed QES degree specializations could provide attractive options for interested students. A deeper picture of why people choose QES will significantly inform the creation of better degree specializations, with additional knock-on effects on graduate EOAS programs."*

In parallel (not explicit in the proposal): *"Attract & inspire appropriate students to pursue QES degrees and to take QES courses."*

QuEST project goals

1. **Critically evaluate** EOAS's current QES degrees, courses and students' experiences.

2. **Characterize** the current state of QES across academic & employment sectors.
3. **Recommend** practical approaches for re-imagining interdisciplinary education and aligning courses & curriculum with existing and emerging employment markets and research priorities.
4. **Suggest** ways to enhance the academic, social and professional experiences of QES students.
5. **Initiate actions and recommendations** to attract, recruit and retain students with quantitative capabilities and interests (e.g. showcase the rewarding & meaningful opportunities available to QES students upon graduation).

2.3 Types of Recommendations

Of the five project goals above, three involve making recommendations. Each recommendation will be characterized as generally targeting either "**curricular**" or "**marketing**" objectives, and aimed at addressing one or more of these specific objectives:

1) Establish new approaches to **inter-disciplinary QES education** across the Earth sciences.
   - ***Why***? to enable our particularly diverse and creative Department to deliver a unique, profound and relevant education in the quantitative Earth sciences.
2) Enhance the **depth, breadth** or **relevance** of quantitative learning both within QES degrees and for non-EOAS students.
   - ***Why***? current learning is somewhat fragmented. Students should be able to attain an increased maturity in these subjects within the 4 years of their degrees.
3) Support **career awareness** and **preparation** for existing students.
   - ***Why***? So our students will be better able to (a) identify opportunities, (b) set appropriate expectations and (c) plan for their success.
4) **Attract** appropriate students into QES degrees.
   - ***Why***? because society needs more quantitatively capable earth scientists.
   - ***Why***? because corresponding EOAS degree programs are under-enrolled.
5) **Inspire** and **motivate** enrolled students regarding quantitative aspects of Earth sciences.
   - ***Why***? to enhance relevance of, and enthusiasm for, these disciplines.
   - ***Why***? to increase the valuable sense of community among QES students & faculty.
6) Foster a **department culture** of efficient & effective engagement with undergraduates.
   - ***Why?*** students have expressed a desire for more of a sense of "community" that includes them within the Department (Jolley, 2020).
   - ***Why?*** being more proactive about supporting undergraduate students will improve the Department's reputation as an attractive place to spend 3 years as an undergraduate.
   - ***Why?*** engaging more meaningfully with undergraduates can be done with minimal "costs" to faculty and is anticipated to enhance the satisfaction of faculty with regards to their responsibilities as educators.

The **21 categories of recommendations** include a total of **149 individual suggested** tactics, tasks or ideas. A table of recommendation tactics summarizes their types, target contexts, impacts and anticipated costs. A list of all specific recommendations with links to pages containing details is also provided.

Note that QuEST is **not** primarily about recommending particular pedagogies, except to sometimes suggest ways of achieving "desirable outcomes".

2.4 Personnel and sources

2.4.1 Personnel

- **Instigators**: Prof. Philippe Tortell, Prof. Christian Schoof
- **Project leads**: Prof. Roger Beckie, Prof. Christian Schoof
- **Project coordinator and researcher**: Francis Jones (Lecturer)
- **Student workers**: Kristie Tai (ATSC student, summer 2022)


P. Tortell


F. Jones


C. Schoof


R. Beckie.

The complete list of 22 EOAS faculty listed as team members on the proposal includes: Philippe Tortell, Christian Schoof, Eldad Haber, Phil Austin, Stephanie Waterman, Susan Allen, Ali Ameli, Roger Beckie, Uli Mayer, Michael Bostock, Catherine Johnson, Mark Jellinek, Richard Pawlowicz, Valentina Radic, Roland Stull, Rachel White, AnaÏs Orsi, Mitch D'Arcy, Tara Ivanochko, Erik Eberhardt, Scott, McDougall, and Brett Gilley.

Others who contributed time and expertise: Carrie Hunter (CTLT), Kimberly Rawes (UBC Career Services), Craig Nichol (UBC-OK), Alison Jolley (STLF in EOAS, 2018-2020).

Funding: AER funding approved. Department has assigned a lead, committee members, and dedicated support of one part time geophysicist / education specialist.

2.4.2 Sources

This is a list of source types, not a reference list. It includes information gathered prior to and during the QuEST project.

1) Information about geoscience careers from AGI, NAGT, AGU, EGBC, SERC, etc..
2) Scholarly literature about career preparation, student motivation and learning. See references.
3) Valuable advice was obtained from – and several research reports were generously prepared by – UBC educational experts, mainly Carey Hunter at UBC's CTLT and Kimberley Rawes at UBC's Career Services.
4) General information from UBC sources (course outcomes, demographics, degree programs, courses, etc.).
5) Engagement with peers and alumni individually or at conferences & workshops, (eg C. Nichols, BCGS and KEGS members, Earth Educator's Rendezvous 2023, email exchanges with academic peers).
6) Interviews or discussions with EOAS faculty.
7) Information about teaching, learning and courses gathered from EOAS instructors.
8) Student survey data, including course or program feedback.
9) EOAS course materials (eg. syllabi).

2.5 METHODS

2.5.1 Research methods

Project goals boil down to describing **current situations** (curriculum, courses and undergraduate QES students' prospects) then identifying and articulating **recommendations** for improving quantitative degree programs & the experiences of students pursuing those degrees.

Most QuEST project work involved researching existing literature, information sources and precedent at peer institutions, and gathering data using surveys, interviews or conversations with faculty, peers, colleagues and students. Valuable advice and several research reports were generously provided by UBC educational experts, mainly Carey Hunter at UBC's CTLT – Academic Program Design and Renewal – and Kimberley Rawes at UBC's Career Services. Resulting data sets and summaries of faculty discussions are summarized in tables on the Data sets, reports & faculty discussions page. Tools and resources created to help with student advising and to characterize current curriculum are listed with pointers on the tools and resources page. We also learned of approaches to curriculum review or renewal from UBC Precedent, especially reports of completed UPER projects, and lists of funded Advancing Education Renewal projects (no reports).

2.5.2 Sequence of project tasks

1) Relevant information reviewed from **activities prior to launching the QuEST project** includes surveys involving students, faculty and alumni, and reports or notes from meetings & faculty conversations. See dated items in the reports and data sets page.
2) **Discussions withing EOAS** prior to COVID are included as items in the reports and data sets tables. Between 2020 and late 2022, most faculty were overwhelmed by the challenges of teaching and running research programs during the global pandemic.
3) **Literature** and useful **web-hosted sources** have been gathered as a Zotero collection owned by F. Jones but visible to public at https://www.zotero.org/groups/4680105/qes_curriculum/library. References cited throughout this QuEST project reporting website are on the references page.
4) Information from seven **peer institutions** about their quantitative Earth science degree programs was compiled via email by C. Schoof, and from public information by C. Hunter. These data are discussed on the Department & Institutional Context page.
5) Insights about **societal demand** for geoscientists in general and quantitative specialists (geophysicists, atmospheric scientists, etc.) are continually compiled by at least 10 different government or professional organizations. Organizations with selected specific pointers are listed on our About Quantitative Earth Science Professions page. A Departmental (EOAS) report from 2010 about **geoscience hiring practices** is also referenced.
6) **Demand for geophysics and geoscience** degree programs across Canada and in other countries was also assessed using EOAS enrollment history, data from the Council of Chairs of Canadian Earth Science Departments, the literature about geoscience education and interactions with peers. Results are compiled on the Demand for geoscience & related expertise page.
7) **Students' experiences** within EOAS were investigated by survey and focus groups in spring 2020. Results provide insightful student perspectives.
8) **EOAS course syllabi, including course learning objectives** were reviewed, assessed, and summarized to identify strengths, weakness and opportunities for improvement.
9) A **new EOSC 1xx course** (likely on climate physics) targeting quantitatively minded 1st yr students has been discussed and some options proposed. A summary of deliberations to date was prepared and the options have been summarized as part of QuEST project recommendations.
10) **Enrollments and demographics in EOAS first year courses** were obtained from UBC's Planning and Institutional Research Office (PAIR) to learn about which students take these courses in terms

of degree programs, year levels and their final grades. The summary report provides insights about who is taking EOSC/ATSC 1xx courses and how well they do.

11) Detailed **course dependency maps** for EOAS quantitative courses only (i.e. not geology, biology, etc.) have been generated including prerequisite courses outside EOAS (such as math, physics and chemistry). The interactive pages start at here and observations about limitations and opportunities based on these maps are summarized on the Current Course Sequences page.
12) The **quantitative content** that students are taught has been compiled here based on information provided by instructors (at least for courses for which relevant instructors responded to requests). Corresponding **learning tasks** have also been compiled and summarized on the Current EOAS Course Content page.
13) The perceived **current and future identity** of EOAS was explored by conducting paired interviews with EOAS faculty. Interviews were conducted by C. Hunter from the curriculum support group at CTLT. Summary report was prepared and results incorporated into choices made about recommendations and resources.
14) EOAS perspectives on **balancing learning about fundamentals versus career preparation** were explored by conducting individual interviews with faculty in summer 2022. Interviews were conducted by worklearn student C. Tai. A summary report was prepared and insights have been incorporated into recommendations and resources.
15) **Workshops** at the annual Earth Educator's Rendezvous conference were attended by FJ in July 2023, providing much insight from colleagues at other institutions about geoscience curriculum and especially regarding career preparation for geoscience students. Lessons learned and examples sited have been incorporated in QuEST outcomes.
16) **Resources for students and advisors** were prepared during QuEST research and results preparation – see below. These actions taken could have been left as recommendations, but timing, availability of people and resources and potential for immediate benefits justified spending QuEST time on these actions in addition to the more constrained objectives of only preparing background material and recommendations.
17) **Showcasing student products,** work or experiences was discussed with CTLT's Web Strategy Manager, Novak Rogic. Results included several examples of student content that other units have explored, but the conclusion was that most ended up being unsustainable owing to time/energy required by faculty.
18) **Marketing materials** for quantitative degree programs to support recruitment, outreach, and internal (eg. advising) purposes has received significant attention. Actions completed or underway are listed on the Marketing Activities page, while recommendations for further actions related to visibility, recruitment, outreach and advising are detailed on the Marketing Recommendations page.
19) A worklearn student was to have been hired to pursue **marketing initiatives** (LinkedIn research, job markets, etc.) for summer 2023, however the student chosen ended up not having suitable temporary immigration status and this was discovered after the worklearn procedures for hiring were closed.
20) **Organizing, summarizing and clarifying recommendations** has been the last step.

2.5.3 Resources for students and advisors

Materials prepared during the QuEST project are listed on the Tools and Resources page. These are intended to clarify expectations (eg for advising), support curricular discussions (eg. interactive curriculum maps),

- A list of scholarships available to geophysics students.
- A new mapping of EOAS courses onto the qualification requirements for professional registration. Liaison with EGBC has been established and the newly prepared "self check list" for students to

map courses they take onto registration requirements will become official with EGBC probably by early 2024.
- An advising tool (spreadsheet) to help students and advisors map course choices onto degree, FoS and EGBC requirements.
- A new Canvas "course" or resource to support advising, career preparation and professional registration.
- **Current state** of QES degree programs and courses, current demand for geoscience degrees and professions and the local departmental and institutional contexts have been characterized in several pages in the "Currently" section of QuEST documentation.
- Reports about two aspects of curriculum renewal were prepared to provide background and justification for corresponding recommendations. These include (1) the what/why/how of **capstone experiences** in degree programs and (2) a brief literature review related to incorporating **career preparation into geophysics & math** courses.

2.5.4 Organizing recommendations

Preliminary thoughts about recommendations were accumulated as they occurred throughout the project period. Categories of recommendations were initially based on four "implementation levels": courses, course sequences, degrees and department level. This option is not perfect as many recommendations involve several "implementation levels". Similarly, organizing by project goals is also awkward since many recommendations address several project goals. Several recommendations involve implementation that spans EOAS degree specializations, even though they emerged as suggestions for ways of rejuvenating the specifically quantitative specializations.

As the data gathering phase wound down (winter-spring 2023), recommendations were re-articulated and classified to indicate implementation level(s), targeted project goal(s), urgency and costs. A table summarizes final choices for categorizing recommendations. Each numbered recommendation is "generic" in nature, and specific actions that could contribute towards addressing that recommendation are presented as a list on pages in the Recommendations section of QuEST documentation.

2.6 A STUDENT-CENTRIC PERSPECTIVE

Before delving into curricular reform and marketing of quantitative Earth science degree programs, it is worth being reminded that this is about students. What is their perspective regarding education and the undergraduate university experience?

Individual faculty members are certainly authorities in their own areas of expertise. Two challenges to keep in mind are: (a) "how people gain expertise in particular domains" is not always well understood by subject-specialists, and (b) the focus is on preparing undergraduates for their needs upon graduation, not on preparing future PhD-capable scientists, nor even preparing every student to become "expert" in every topic they are studying. Students who choose to go on to graduate studies (roughly 20%) will delve into detailed fundamentals as graduate students. On the other hand, roughly 80% of BSc. students need to develop abilities that will help them get hired into their first meaningful job and succeed in the workforce.

This does not mean our role at UBC is purely to "train workers". University education is certainly different from trade school. The benefits of succeeding in a BSc. program at a tier-1 research university like UBC include both the breadth gained across disciplines (i.e. progress towards become a well-rounded, educated citizen) and an appreciation of the fundamentals that underlie the concepts, skills and habits they will use as employees, even if the depth of that appreciation is not at the level of "experts".

The QuEST project has learned from undergraduate students using personal conversations, course and program feedback data & comments (eg Jolley, 2020), from undergraduate and graduate project employees, teaching assistants, and from precedent reported by other institutions, via workshops, peer discussions and peer reviewed literature.

2.6.1 Thinking about future courses & curriculum: How to factor in the "*evolving characteristics of students*"?

The influences on undergraduate experiences – individual background, the social conditions and events, opportunities and challenges – are distinct for every generation. Students arrive at UBC with prior experiences different from ours, and with concerns and priorities that may be unique to their times. How can we design and deliver curricula and learning experiences that will be inspiring and which will prepare them to be effective contributors in the decades beyond graduation?

The spotlight article in the **Fall 2023 edition** of the UBC Magazine (a publication of alumni-ubc) offers a glimpse of characteristics unique to undergraduate students in 2023. The article includes perspectives and quotes from Esmé Decker, the current (2023/24) AMS president, Ainsley Carry, the current vice-president students, and UBC sociologist Neil Armitage who was also with the Centre for Student Involvement and Careers. The article is short and thought-provoking. Here are some notable quotes and take-away messages to keep in mind as we tackle current and future curricular initiatives.

Students' priorities

- Students are more globally-minded and have more avenues of communication and self-expression. Big picture issues are more prominent in their minds, especially climate, justice, equity, inclusion and the like.
- They are eager to lead change on campus but also eager to contribute more widely in the professional world beyond the academic "ivory tower".
- The current AMS president was elected on a platform of climate action and food security, and is active with the student group Climate Justice UBC, and the UBC Climate Hub.
- "*No generation has been as well equipped to rally around such a massive global issue*".

About learning today compared to "yesterday":

- New theories of student development place emphasis on pre-enrollment experiences and traumas, including personal, racism, immigration and mental health issues among others.
- The rise of high-tech learning may have permanently changed how current and future students think of education in general. They have quick access, on-demand, and tech-centric perspectives.
- Students apparently think "*just give me access to information and I'll learn it*". Also, many instructors still assume that their job is to "*deliver the information*". However, we now know better; learning is about "*practicing new skills and capabilities*" not "*learning information*". And it is our (instructors') responsibility to help students engage with challenges and adjust their expectations accordingly.
- Regarding reasons for attending university: "*Students are working on careers the moment they step on campus*." They "*view university as a stepping-stone rather than a rewarding experience in and of itself. Students can be like cost/benefit analysts …* " therefore it is unwise to assume they are driven by curiosity and "interest" to the same extent as professional research scientists.
- "*Academics are very good at explaining the issues but not always good at addressing them*".

2.7 FRAMEWORKS FOR CURRICULUM RENEWAL

There is plenty of precedent for approaches to curriculum renewal, both at UBC and in the wider science, STEM and geoscience education literature. A few selected aspects that have been front-of-mind throughout preparation of recommendations are summarized here.

>>UBC's process for "program renewal" includes six types of goals, each of which align closely with QuEST project's objectives .

1) Reviewing and re-imagining the academic direction of a degree specialization.
2) Understanding and improving student learning experiences.
3) Managing program growth, *[or in our case striving for growth].*
4) Offering greater transparency about programs *[to benefit existing students, potential or prospective students and EOAS faculty].*
5) Ensuring that programs prepare graduates for the next stage of their life *[to ensure that "career preparation" meets the needs of as many students as possible].*
6) For accredited programs, ensuring programs meet required standards or competencies *[bearing in mind that roughly 80% students want to pursue careers upon graduation and some of the normal career pathways for QES graduates require registration as professionals]*.

>>Process and experiences described in Kwok, 2018 regarding science curriculum reform at Hon Kong University between 2006 and 2012. Their goals involved the wider scope of science education generally while our objective is focused on quantitative Earth science disciplines. However, rational, initiatives and lessons learned by the Hong Kong University curricular renewal project are germane to our narrower initiative. For example, the following considerations for reforming courses are adapted from those expressed by the author:

- Are all courses in each degree specialization really necessary?
- Each course should focus on the fundamentals and not be overly specialized.
- Courses should be designed for the benefit of students, not the convenience of the instructors. Some courses reflect the research specialties of individual faculty members, which may not be essential to a particular major.
- The degree's curriculum should be flexible enough to allow discipline-dedicated students to gain the in-depth knowledge expected for entry to graduate school but also allow the majority of students to have a broad, meaningful and appropriate education that makes them attractive to prospective employers.

>>Interdisciplinary Curriculum Design is discussed in some detail in Modo and Kinchin, 2013. Their context is neuroscience, considered significantly "interdisciplinary", and hence a good analogy for QES curriculum design.

>>An insightful case history of curriculum development is "*A faculty team works to create content linkages among various courses to increase meaningful learning of targeted concepts of microbiology*", Marbach-Ad et al., 2007.

>>Precedent regarding crafting of program learning objectives; To clearly characterize an existing, proposed, or updated degree program, carefully crafted Program Learning Outcomes or PLOs must be constructed (an iterative process): There are many frameworks for developing or reviewing PLOs, but one example is the Degree Qualifications Profile (Gaston, Schneider, and Ewell, 2022). Existing precedent does not necessarily have to be used rigorously, but it may help ensure a "structured" consideration of curriculum. More locally, CTLT will be eager to help formulate and optimize PLOs. See their PLO page.

>>Transparency of teaching practices is important for all stake holders, especially students. The TILT Higher Education model of Winkelmes, 2023 (TILT = Transparency in Learning and Teaching) provides insights and guidelines to help ensure equitable teaching and learning practices by promoting students' conscious understanding of *how* they learn and by enabling faculty to gather, share and promptly benefit from *current data about students' learning* by coordinating their efforts across disciplines.

>>An emphasis on "authentic learning" permeates all suggested curricular innovations or adjustments. This is to ensure students can connect what they learn, practice and create to real-world issues, problems & applications.

2.7.1 Framework for embedding career preparation into degree experiences

One of the principal recommendations emerging from QuEST to increase the focus on career preparation without compromising the benefits of learning fundamentals in a top research university. The annotated bibliography and notes generously prepared for QuEST by K. Rawes, includes the following useful framework for how this can be done:

1) **Professional preparation** - activities, lectures, or assignments where students learn about their strengths, write personal philosophy statements, listen to alumni guest speakers, or practice career management skills (resume writing, interviewing, or researching labour market data).
2) **Discipline-specific experiences** - students gain credit for discipline-specific experiential learning like research projects, community-based experiential learning, internships, practicums, co-ops, field school, international study, etc.
3) **Pedagogies and course-design** - students develop future work competencies – like complex problem solving or communication – as a result of activities like presentations, team assignments, real-world case studies, ePortfolios, etc.
4) **Applied learning** - Capstones or applied research projects create opportunities for students to integrate learning from multiple sources or experiences and/or apply theoretical learning to real-world problems.

2.7.2 Regarding pedagogy

Detailed suggestions for adjusting pedagogy in particular settings (a course, lab, assignment, etc.) are largely out-of-scope for this report, partly because pedagogic "best practices" for STEM learning are mostly ubiquitous – i.e. not specific to the learning of quantitative Earth science subject knowledge or skills.

There may be some teaching or learning tactics that are particularly relevant in courses focusing on math, statistics, data science or computing. However, improving pedagogy in specific settings should be an ongoing process addressed by individuals with departmental and institutional support in the form of time, resources and educational expertise. EOAS expects to continue developing and applying established pedagogic best practices to help students set appropriate expectations, develop their learning skills and succeed in their chosen courses & careers. Examples include continued development of active learning tactics & group work, explicit use of *learn -> apply -> practice* cycles throughout the curriculum, and others. Having said that, some specific aspects of pedagogy will be mentioned within the recommendations section, to identify opportunities for improving QES learning within EOAS.

Examples of tactics that are highly recommended regardless of course or content:

- Improving program and course-level learning outcomes as well as syllabi;
- Introducing (or improving) capstone experiences in a course or program;
- Emphasizing career-related contexts that encourage development of professional behaviours.

- Students and instructors benefit when students can determine if their prior knowledge is adequate at the start of a course, AND resources are provided to help students catch up with common missing skills or knowledge. Several EOAS courses are doing this; EOSC 340, EOSC 354, and MATH255 at UBC-OK.
- Pay attention to semantics and jargon, especially "normal" words that take on special meaning within the context of the discipline.
- Consult with colleagues and science education specialists (and CTLT) introduce imaginative, stimulating tactics that inspire, motivate and increase retention and skills.
- Many EOAS courses are now quite active in terms of students being effectively engaged during class, lab and homework time. However others could benefit from less "telling" and more "guided doing" during lessons, assignments and assessments.

2.8 Next steps: priorities beyond QuEST

What's next? I would suggest that the next step is to identify the Department's priorities, concentrating on practicalities that depend on whether a "champion" or project coordinator (i.e. someone to do all the leg work) can be found. Hopefully these recommendations and all the background information will be useful to the future "concrete" quantitative Earth science curriculum development projects.

Here are some top priorities based on the work and 'discoveries' during the QuEST project. Choices made will require a balance between individual and collective preferences and the practicalities of implementation. ***Priorities are likely to evolve based on discussions with stakeholders.***

1. **Implementation tactics**: once a clearly defined objective has been identified, consider incorporating a **SWOT** approach to identify **s**trengths and **w**eakness of existing situation as well as the **o**pportunities and **t**hreats (or barriers) associated with accomplishing the goal. A prepared worksheet for carrying out a SWOT analysis is available here (MSWord) or here (PDF).
2. **Getting buy-in** will be a key aspect of rejuvenating curriculum. See ...\QUEST\background\Getting Buy-In from Colleagues.docx, downloaded from online doc generated during EER 2023. Needs refining and delivering as PDF.
3. Establish **consensus regarding the undergraduate quantitative capabilities** that are consistent and compatible across the QES disciplines within EOAS.
4. **More regular interaction** between quantitative faculty and the EOAS communications team will help make EOAS's QES opportunities more visible, attractive and relevant.
5. **Support for students** needs revisiting and prioritizing. Student success and effective recruiting depend on staying current with how their needs and stressors evolve from year to year, and providing corresponding mentoring as effectively as possible with available resources (time, energy, costs).
6. **Recruitment** or "marketing" of QES opportunities pervades QuEST recommendations. Adjustments to courses and curriculum are all just as much about making QES degrees visible & inspiring as they are about refining the capabilities students will develop.
7. **Career preparation** includes raising *awareness* of opportunities, fostering *authentic* learning (fundamentals in relevant contexts), enabling *reflection* about relevance of learning, and helping students develop *personal capabilities and attitudes* to ensure they are prepared for the increasingly diverse and competitive workforce.
8. **Climate issues** are a primary concern for current students. A more "rigorous" (although still accessible to appropriate first year students) first year course about climate science (or climate physics) is likely to be well-received. But make sure it has an "eye-catching" public face. Maybe "climate physics" is the wrong title since it seems daunting.

9. QES curricular deliberations need to engage with current and emerging **environmental sciences** and the **sustainability** initiatives across campus - T. Ivanochko is the Department's point-person on these efforts.

3 Current Curriculum and Context

QuEST goal #1: Critically evaluate current QES degrees, courses, students' experiences, and career opportunities.

These four pages outline the current degree programs and courses in EOAS, emphasizing quantitative Earth sciences (QES). The aim is to characterize "what is" so that recommendations about what we could do to re-invigorate these degree programs and courses are grounded in the current state. "Critically evaluate" means consider implications and offer some measure of critique. The ultimate project goal is to generate recommendations, but some critique will help establish which recommendations may become priorities.

3.1 Current degree specializations

This page is simply a short summary of undergraduate degrees currently offered in the Department of EOAS and serves to define the quantitative Earth science disciplines for the purposes of the QuEST project. Discussions about possible adjustments to degree programs, or alternatives, are in the "possibilities" page, and corresponding recommendations are on the degrees recommendations page.

B.Sc. majors, honors and combined degrees are offered in six subject areas: Geophysics, Atmospheric Sciences, Oceanography, Geological Sciences, Earth & Ocean Sciences, and Environmental Sciences. A **B.A.Sc.** degree in Geological Engineering is also offered. Details are on the EOAS "degrees" web page.

Official degree requirements for all Faculty of Science degree specializations can be found starting at UBC's Bachelor of Science degrees calendar page.

The first three (Geophysics, Atmospheric Sciences & Oceanography) are considered the more "quantitative" or math/physics/computing oriented B.Sc. degree specializations. For the purposes of the QuEST project, these are considered the **Quantitative Earth Science** or **QES** disciplines.

See **UBC calendar**: https://vancouver.calendar.ubc.ca/faculties-colleges-and-schools/faculty-science/bachelor-science
Numbering indicates the order presented on corresponding UBC calendar pages.
Colours indicate similarities.

Ability	ATSC	OCGY	GEOPH
Basic science	1. **demonstrate** basic knowledge of atmospheric physics, dynamics, and chemistry on a wide range of scales;	1. **demonstrate** basic knowledge about the chemical and physical ocean environment with emphasis on biological processes and chemical processes;	1. **demonstrate** basic knowledge of the physics of the Earth and other planets;
Numerical & computing methods	3. **use** numerical problem solving, computer programming, mathematical knowledge and statistical approaches for data analysis and atmospheric modelling;	3. **use** numerical problem solving (using computer programming skills) both with models and real data;	3. **use** numerical problem solving, computer programming skills, statistical approaches and inverse theory for data analysis and modelling;
Synthesis	6. **integrate** meteorological knowledge with broader issues including air quality, environment, sustainability, renewable energy, and climate variability;	6. **integrate** concepts across multiple levels of biological complexity (i.e., biochemical, physiological, organismal, and ecological);	5. **integrate** theory, observations, and/or numerics to solve geophysics and related geoscience or technical problems;
Communication	4. **communicate** (written, oral, electronic) weather information to a broad audience;	8. **write** reports and **communicate** through oral presentations;	7. **use** relevant scientific and technical literature, **write** reports and communicate through oral presentations;
Field	5. **deploy and utilize** meteorological field and lab instruments and data loggers;	4. **use** basic field/laboratory skills for observation and experimentation in biological oceanography;	
Math & analytic methods		2. **use** mathematical knowledge including calculus and statistical techniques for environmental set up and data analysis;	2. **use** analytical problem solving and mathematical techniques for model development;
Data / experiment / theory / models		5. **illustrate** the distinctions between data, experiment, theory, and model;	4. **illustrate** the distinctions between data, experiment, theory, and model;
Application	2. **utilize** information from weather radar, satellites, numerical weather prediction, weather maps, and soundings **to form a 3-D understanding** of atmospheric state and evolution;		6. **apply** geophysical approaches **to understand** the structure and dynamics of Earth and other planetary bodies, including their climates, surface evolution and internal composition;
Independence & lifelong learning		7. **conduct** independent study on a topic of their choosing;	

Table of official program learning objectives for QES degree programs, summarized for comparison. Click the table to see full-page PDF version.

Students in other specializations do of course develop quantitative capabilities, and many recommendations emerging from the QuEST project will be relevant in those courses and degree programs. However, the focus is mainly on the primarily quantitative disciplines.

3.1.1 Professional Registration for EOAS graduates

Keeping professional registration requirements in mind while considering courses, curriculum and student experiences is necessary because all geoscience professionals working in Canada, as well as many working in environmental disciplines, are legally required to become licensed with their provincial associations if they want to work without supervision (just like nurses, lawyers, etc.). Students expect to be qualified to work in their chosen professions upon graduation, therefore the curricula making up corresponding degrees must prepare students appropriately. Even graduate students should bear this reality in mind.

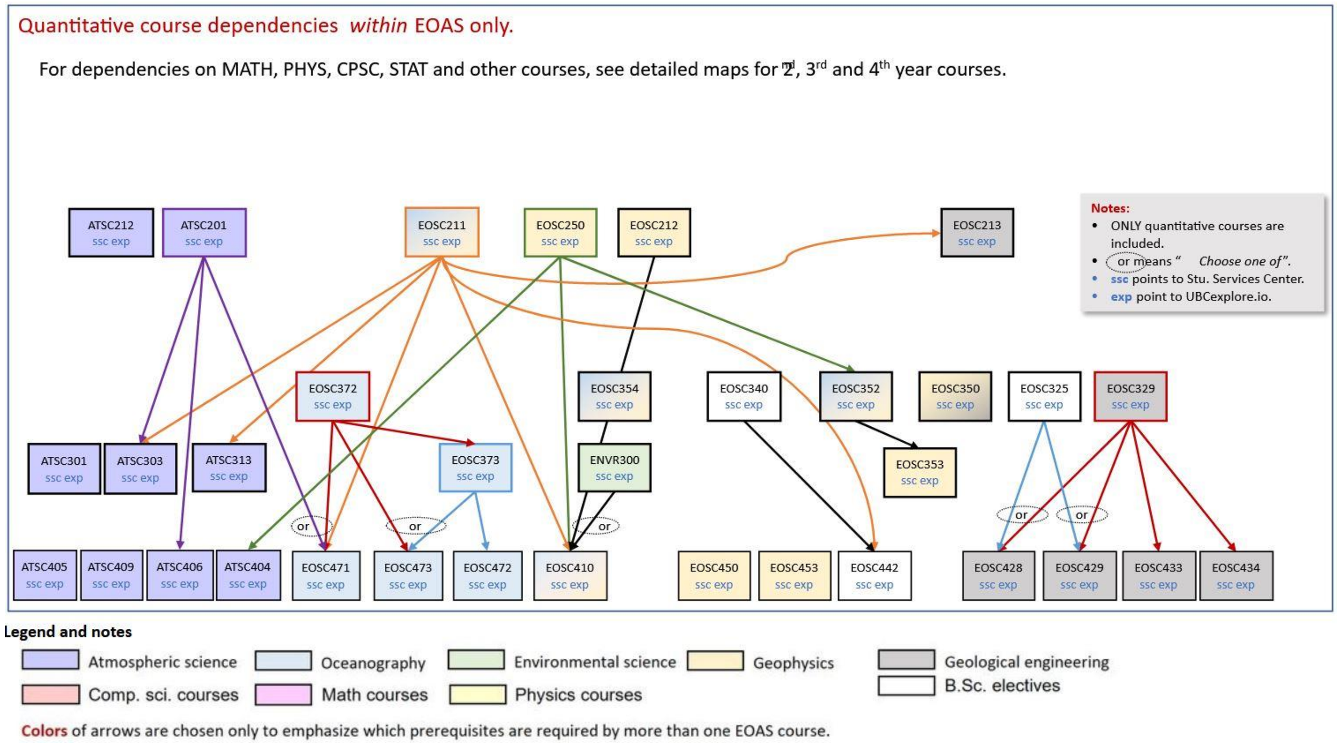
Pursuing graduate work and obtaining an MSc or PhD in the geosciences only counts to some extent as "experience". The prospective licensee still requires the academic credentials obtained by taking the necessary undergraduate courses. So getting that right as an undergraduate will make it much easier to register eventually when the individual finally leaves academics to work as a geoscience professional. Of course – these considerations are less relevant if they end up working in some field other than the geosciences.

Discussions and recommendations are detailed on a separate professional registration page.

3.2 CURRENT COURSE SEQUENCES

3.2.1 Curriculum maps for QES courses

Many courses offered by our department (course codes EOSC, ATSC, ENVR) involve developing quantitative skills. however the 34 courses in the course dependencies maps (next figure) are the main focus of the QuEST project. They are the courses that emphasize, or use, advanced mathematics (beyond first year calculus), physics or computing. Click here to explore the four interactive maps on the EOAS website.



The goal of this resource is to help **visualize and explore** the dependencies *between* quantitative EOAS courses, and all *prerequisite* courses required for these 2nd, 3rd, and 4th year EOAS courses. Instructions are included for using and building these types of interactive pages.

3.2.2 Observations based on QES curriculum maps

The following observations are about the official *dependencies* between courses. Aspects of curriculum **not** addressed here are those related to specific learning goals, topics, the needs of employers and interests or priorities of students.

Reasons for reviewing official prerequisite dependencies include:

- formal prerequisite requirements are the strongest indicator of curricular flow, so it is worth examining how courses depend on each other.
- identifying courses that assume no prerequisite quantitative capabilities, and to then consider whether that is appropriate, and why;
- finding courses that other courses do not depend upon – especially if they are in 1st or 2nd year. These may represent lost opportunities for more senior courses to benefit from prior knowledge that students will gain in an that earlier course. Or they may suggest courses that are contributing less than they could to students' success. This situation also suggests to students that capabilities gained are "less important" because they are never used again within their degree's curriculum;

- identifying courses that accept more than one prerequisite and consider whether the alternatives are in fact providing equivalent prior capabilities;
- reflecting on whether a given course actually does make use of the current prerequisites;
- Informal relationships certainly exist between courses but these are not considered here as they are more a matter of individual instructors' decisions.

3.2.3 General observations & questions

Many instances of "implied prerequisites" exist in the form of curricular requirements. As one example, EOSC211 is required for 2nd year geophysics students but not a prerequisite for EOSC354 (time series analysis) in which students carry out significant computing.

Therefore, explicit prerequisites could be considered less important for courses taken only by students in specific specializations because degree requirements specify the courses that are necessary. For courses available to students outside of EOAS, prerequisites are more important since instructors can't count on "assumed" capabilities learned in previous courses.

"Corequisites" are only mentioned twice, once for EOSC250 and once for ATSC404. Are those requirements working as planned?

3.2.3.1 200-level courses

1) EOSC213 is not *required* by any other course in EOAS, and only as "one of" 3, for CIVL417. See "dependent courses" near end of this page.
2) EOSC211 and DSCI100. These are both "first exposure to programming", although DSCI100 is more fundamentally a statistics course, while EOSC211 is introductory programming in an Earth sciences context.
   a) Only four EOAS courses taken by **B.Sc.** EOAS students require EOSC211. However, the course is required by some programs, so students will have taken it (or equivalent) weather it is a formal prerequisite or not.
   b) For any course requiring EOSC211, should DSCI100 count too? Currently, ATSC313 is the only EOAS course with DSCI100 as a "one-of" prerequisite.
   c) However, DSCI100 does fill a need with respect to exposure to elementary statistics.
   d) Geophysics has included DSCI100 in required courses (or, with permission, another 2xx statistics course). Other EOAS programs do not DSCI100. This gives geophysics students an advantage regarding programming skills when they take EOSC211, yet they are likely the students least in need of it. Does this increase the bimodal nature of student success in EOSC211? Maybe geophysics should require either DSCI100 or EOSC211?
   e) Student feedback from Dawson club members, reported March 11, 2022: "*significant proportion of the class gets lost very soon and never really gets it. Peers attempt to support but often without seeing any breakthrough in understanding*". Details not conveyed, but dissatisfaction seems fairly widespread.
3) EOSC250:
   a) What in MATH200 as coreq is important? Or – why not make it a prerequisite (or MATH253) like EOSC213?
   b) Are there opportunities for employing computing either as part of problem-solving or (perhaps more appropriately) for introducing interactive concept demonstrations, and contexts that are easily identifiable as "important" rather than "scientifically interesting". This is about motivation as the course leaves a rather "dry" and "unattractive" public-facing impression.
4) EOSC212 is not required by any EOAS courses.
   a) However, it is required by geophysics (212 or a 1xx +111), geology and EOS degrees.

    b) Perhaps there could be at least one "module" in which "scientific thinking" (the course's theme) is incorporated into an industry or commercial?
5) ATSC212, EOSC256, EOSC355; are these "redundant"? Should they be deleted from the UBC calendar?

3.2.3.2 300-level courses

1) At 3rd year level, only ATSC303 and ATSC313 have any explicit computing prerequisites. Not even EOSC211 or DSCI100 are required for any other 300-level QES courses. However, requirements are implicit in degree specifications.
2) Re. EOSC354
    a) There are no computing prerequisites. Geophysics students will have taken EOSC211 so this is not a "problem" for them. However more students might be attracted if it is recognized as a course in which students continue to grow their computing skills.
    b) Could a Calc1 prerequisite be swapped out in favour of "EOSC211 or equivalent"? After all, EOSC211 itself requires Calc1.
    c) Augment the "either/or" physics prerequisites for EOSC354 by adding PHYS153 & PHYS106.
3) EOSC353
    a) EOSC354 not prerequisite for EOSC353, presumably to increase the potential for non-geophysics students to take 353 (seismology). But if 353 does not depend on time series, maybe it should?
    b) Adjust to attract more students: Offer alternate years? Rename to have broader appeal? "Advertise" in Phas/Astron or Civil Eng (eg grads)?
4) Could ATSC303 have more options for computing prereqs? Currently EOSC211 alone is required.
5) Add SCIE001 to any requirements for Calc1 (three 3rd yr courses) or Physics101 (eg EOSC250).
6) ATSC313: augment options for the physics requirement by allowing PHYS153 & 106?

3.2.3.3 400-level courses

1) Two ATSC and two geophysics 4xx courses require no EOAS prerequisites. This possibly helps attract students from other disciplines, but means there is no certainty about student capabilities coming into the course.
2) EOSC410 seems quite restrictive to undergrads (and taken by only ~4-8). See Questions below.
3) The "any programming language" for ATSC405, 409 is vague. Is that OK?
4) Do EOSC 45x really need no computing, or are capabilities assumed owing to 4th yr status in science?
5) Consider having 4xx "specialist" courses include at least some "either or" prerequisites from EOAS, eg ATSC405, 406 and EOSC450, 453.
6) ATSC405: augment Diff Eqns requirement by allowing MATH255 or 256?
7) ATSC404: augment Applied DEs requirement by allowing MATH257?
8) EOSC410:
    a) augment stats requirement to include STAT201 or 251?
    b) augment cmpsc requirement to include five courses in "pink" box?
    c) EOSC410 seems quite restrictive to undergrads (and taken by only ~4-8 students).
        i) Is EOSC212 or ENVR300 necessary if "3rd yr in EOAS is included?
        ii) Is that requirement even necessary? (Probably – but worth discussing because students outside EOAS might be attracted).
        iii) Could single requirement of eosc211 be loosened? Especially if CPSC203 and 210 are required.
        iv) In fact, are CPSC203 and 210 really required?
9) EOSC471: augment requirement to include five courses in "pink" box?

10) Are ATSC405, 406 “redundant”? Should they be deleted?

3.2.4 Prerequisite competencies

Prerequisite competencies (not courses) are listed here for only the quantitative courses in EOAS (not all EOAS courses). Click the image for a full size version in a new tab.

Quantitative Earth Science courses that require math, physics and/or computing prerequisites

**areas represent all "one-of" prerequisite lists of courses that cover that topic area.

- *Courses in italics are mainly for engineers.*

		EOSC 2xx				ATSC 2,3xx				EOSC 3xx									ENVR 3,4xx				ATSC 4xx			EOSC 4xx							
area**	count	211	212	*213*	250	201	301	303	313	325	*329*	340	*350*	352	353	354	372	373	300	410	420	440	404	405	409	410	429	*433*	*434*	442	450	453	471
2nd yr	2		p			p																											
3rd yr	4									p			p						p							p							
4th yr	1																			p													
a prgrm lang	3						p																	p	p								
Compute1	6			p				p	p																	p				p			p
Compute2	1																									p							
IntegCalc	6	p							p		p	p				p	p																
DiffEq	2																							p	p								
VectCalc	3													p									p			p							
MultiVCalc	5			p	c								p										p			p							
LinAlg	2			p			p																										
PDE	2																														p	p	
AppDE	3																						p								p	p	
IntroStats	2																									p				p			
PhysWave	6				p				p			p				p	p																p
PhysEM	3				r		p																								p		
PhysTherm	1																						c										
ChemIntro	2											p					p																
atsc	2							p																									p
hydrog	4																				p						p	p	p				
ENVR200	1																					p											
ENVR300	1																									p							
Sustain'y	1																					p											
EOSC212	1																									p							
EOSC340	1																													p			
EOSC352	1														p																		
EOSC372	2																	p															p
CIVL210	2																											p	p				
MINE303	1																											p					
EOSC330	1																												p				

		211	212	213	250	201	301	303	313	325	329	340	350	352	353	354	372	373	300	410	420	440	404	405	409	410	429	433	434	442	450	453	471
prerequisite	p	1	1	3	1	1	3	2	3	1	1	3	2	1	1	2	3	1	1	1	1	2	3	2	2	8	1	3	3	3	3	2	4
corequisite	c	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
recommended	r	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Comments regarding prerequisite competencies

1) The **most commonly needed prerequisite capabilities** are (number of EOAS courses depending on each prerequisite subject area is in column 2.)
   - First course in computing/programming (6 courses need this),
   - First year integral & differential calculus (6 courses need this).
   - multivariate calculus (5 courses need this),
   - wave physics (6 courses need this).
2) The number of **prerequisite subject areas** (not specific courses) prior to taking each EOAS course is in the bottom 3 rows.
   - EOSC 410 (cross-listed with EOSC 510 for grad students) has prerequisites in 8 subject areas or courses, which seems difficult to achieve for undergrads. In fact there are usually only 4-8 undergrads enrolled.
   - One challenge is that EOAS courses are often electives for other programs and a balance must be found between asking for highly “prepared” capabilities (lots of prerequisites) and accessibility of these courses to a wide range of students.

3) The "**chain of math**" prerequisites via the next figure. Course in cols 1,2 need courses identified in columns 3-16. The 1's indicates "one-of" is the requirement.

Math sequences		MATH100	MATH101	MATH103	MATH105	MATH121	MATH152	MATH221	MATH223	MATH200	MATH217	MATH253	MATH215	MATH255	MATH256
diff. Calc	MATH100														
Integ Calc	MATH101	1								c = corequisite					
	MATH103	1								r = recommended					
	MATH105	1								1 = one-of is required					
	MATH121	1													
Lin.Sys (BASc)	MATH152		c												
Matrix	MATH221		1	1	1	1									
Lin Alg.	MATH223		1	1	1	1									
MultiVar. Calc	MATH200		1	1	1	1									
	MATH217		1	1	1	1	c	c	c						
	MATH253		1	1	1	1									
Diff Eqns	MATH215		1	1	1	1	1	1	1	c	c	c			
ODEs	MATH255		1	1	1	1	1	1	1	c	c	c			
DE	MATH256		1	1	1	1	1	1	1	c	c	c			
Calc IV	MATH317						r	r	r	1		1			
PDEs	MATH257												1	1	1
Des II	MATH316												1	1	1
Intro MathPhys	PHYS312												1		
	STAT200		1	1	1	1									

4) **Advising**: students see a variety of courses for each subject area (such as "integral calculus"). They should choose the correct option for their degree specialization and ensure that courses are taken in the right sequence. Therefore, well-informed advising is important, and the correct academic calendar needs to be followed carefully. (Further details under Student Support.)
5) **Detailing math needs**: For EOAS courses, math dependencies need more rigorous review by mapping actual content in EOAS courses identifying how the math prerequisite knowledge is relevant. This could be "by implication" as developing mathematical "maturity" is important, but clarifying how early math courses impact capabilities for later EOAS courses should be part of a curriculum review process.

3.3 CURRENT EOAS COURSE CONTENT

Here we summarize what students are learning and experiencing in EOAS QES courses. Four sections are:

A. Syllabi & goals for current QES courses
B. QES course content
C. Students' QES learning tasks
D. Computing in EOAS

3.3.1 A. Syllabi & goals for current QES courses

Characteristics of syllabi and learning goals from 27 QES courses were obtained using a survey to EOAS instructors. Many of these syllabi are actually not too bad. However, there are straight forward steps that would improve their effectiveness at improving both clarity of aims and effectiveness of learning in each course. See the courses-level recommendations page for details.

Results of characterizing syllabi and learning goals are in a **5-page report** (including figures) which has the following outline:

1) **Background**: discusses why a complete and consistent syllabus is needed for every course.

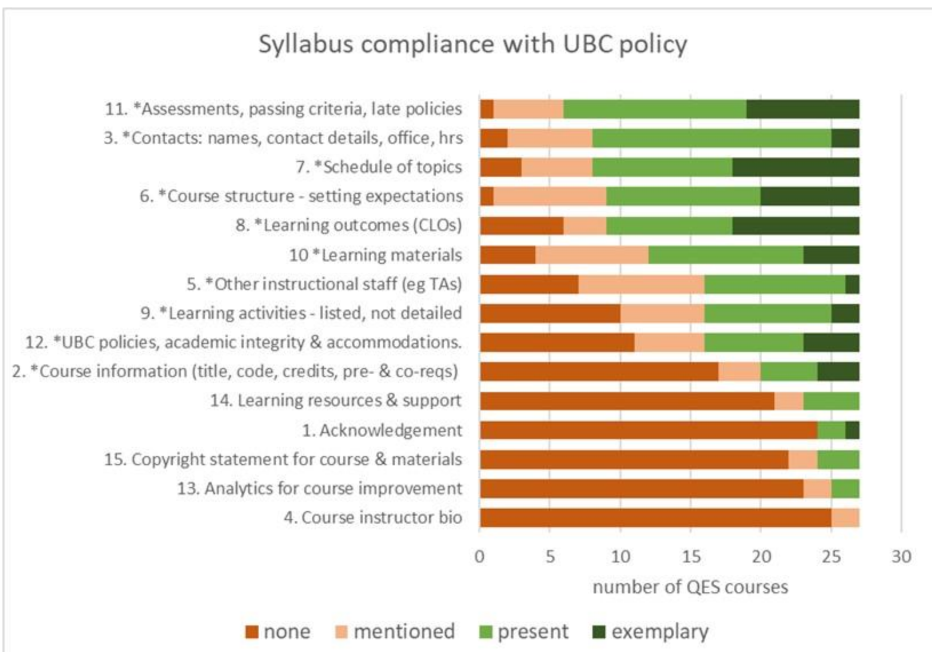
a) **An ideal syllabus includes**: lists 8 aspects that should be provided by a syllabus
b) **Contents of UBC's recommended syllabus**: The 17 recommended items are listed and the 12 that are *required* by [Policy V-130] are emphasized.

2) **A Sampling of EOAS Syllabi**: the request for data is described

a) **Where are syllabi provided**? The goal here is to see how "publicly visible" the syllabi are for these courses (a syllabus should ideally be a public document). Figure here summarizes the visibility of syllabi reviewed.

Number of courses with syllabus at each location	
Instructor's website or page at EOAS	8
Not publicaly available (or on Canvas)	6
Privately on the EOAS Owncloud server	5
EOAS course homepage	4
GitHub (instructors or other)	3
instructor's other website	1

b) **Completeness**: to what extent are items that are recommended or required by the UBC template present in the syllabi provided? Figure here summarizes the extent to which UBC's required or recommended criteria are being met across the syllabi reviewed. *Stared items are required by [Policy V-130]



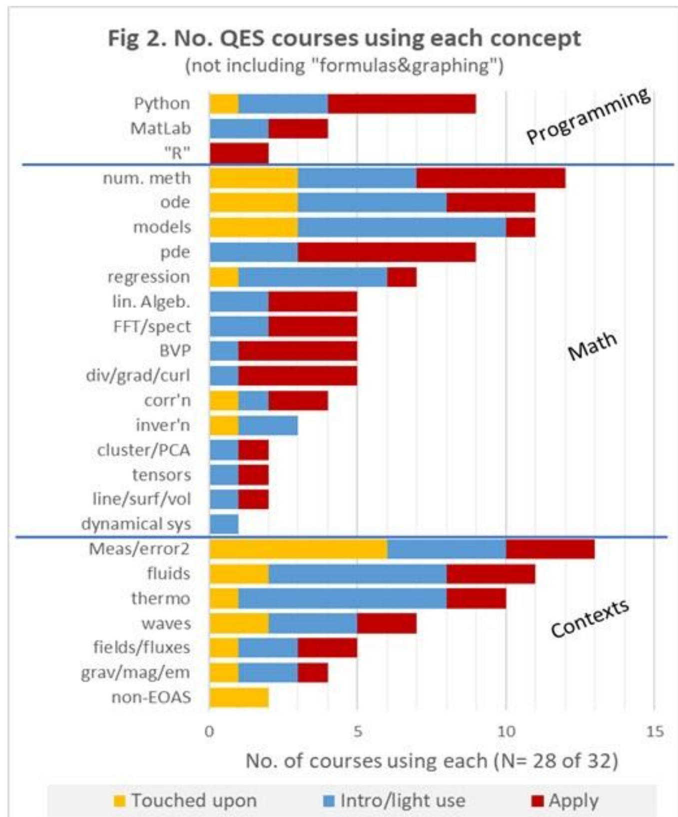
c) **Course Learning Outcomes (CLOs):** Updating learning goals is both important and challenging. Goals provided in the 27 syllabi were assessed to be either "exemplary", "present", "mentioned" or "none". These goals turned out to be not too bad, however, there is certainly room for improvement, and for striving for consistency.

d) **A possible framework for CLOs**: There are advantages to asking for some sort of "standards" when writing learning outcomes for a course. This section of the [report] suggests a framework for characterize CLOs in terms of 4 types of characteristics.

3.3.2 B. QES course content

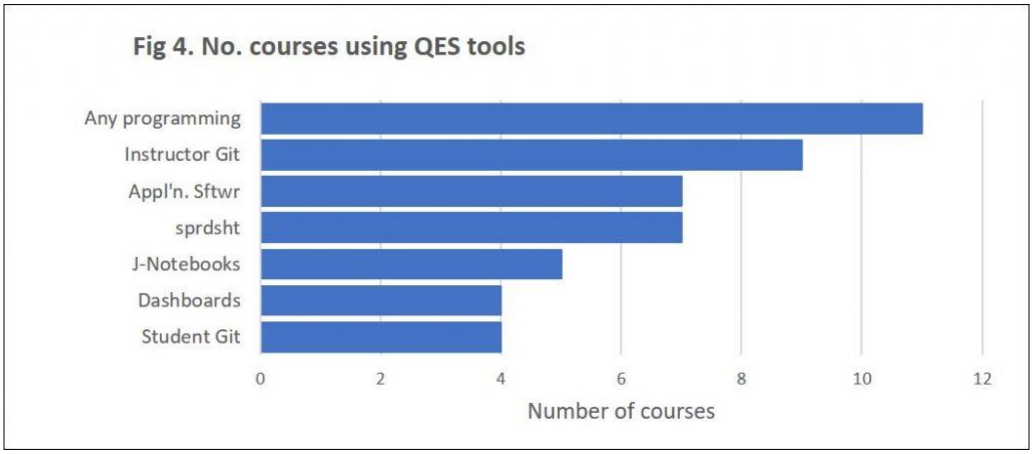
Results of asking faculty at the 2019 Dep't retreat to "*list quantitative skills & learning students are exposed to (or you would like to see them use)*" are tabulated here. The question was open ended, yielding 25 "types" of quantitative skills spanning six EOAS specializations. That listing is likely incomplete since some skill types that seem "obvious" are missing from some specializations. For example, no skills related to data visualization were included in the geophysics column, yet geophysical data of all types needs visualizing as part of analysis, interpretation and modeling.

During the 2020/21 teaching season, instructors of 28 QES courses provided information about quantitative concepts learned, and contexts used for that learning. The report based on these data includes the following sections:



1. **Data gathered**: received for 25 courses, estimated for 3 more, and not received from 4. Concepts and contexts were established based on the forms. For each course, each concept was interpreted to have been taught at one of four levels: none; touched upon; intro/light use; application.
   1. **Data quality**: Two questions were asked, but no guidelines were provided, so information returned ranged from cursory to detailed.
   2. Also, the number of times that each concept was 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.
2. **Summary of interpreted results**: *Fig. 2* summarizes the number of courses using each of 25 concepts. The report presents some observations, conclusions and recommendations. The number of topics addressed in each course is also discussed.

3. Also, the number of courses **using** each of 7 quantitative "tools" is discussed briefly (*Fig. 4*).



4. **Recommended next steps**: These data might best be used as a starting point for discussions about what could be taught, what "should" be taught bearing in mind the likely needs of graduating students. See the Desirable Skills section for discussion on what could be taught.
5. **Data tables**: this appendix lists courses, instructors and QES concepts that emerged from analysis.

In addition to survey data above, EOAS faculty discussed quantitative content at the 2019 departmental retreat. Results are incomplete as they were not been vetted by all EOAS faculty. A summary by degree specialization is in the PDF table here, and listed here (perhaps more informatively) highlighting types of QES skills compared across degree specializations. Thirty two specific quantitative skills are listed, some more generic than others. For example "calculus" is quoted as developed in 5 courses, whereas vector calculus, ODEs, PDEs, numerical analysis and others are also listed. Adjustments should be made for changes made since 2019, especially in terms of programming skills which are now focused around Python rather than MatLab and "R".

3.3.3 C. Students' QES learning tasks

To learn about what students do to learn, and resources they are provided with a brief survey was generated, reviewed by educational expert (K. Rawes, UBC's Career Servicies), and deployed using UBC's Qualtrics survey tool. Two out of the five questions were inspired by the Teaching Practices Inventory (Wieman & Gilbert, 2014)). The survey questions themselves can be seen here.

All instructors were asked to complete the survey, and results were obtained from 50 out of 68 EOSC, ATSC and ENVR courses. The following table summarizes courses for which we obtained data compared to the number of courses of each type in EOAS. At least two thirds of courses for each discipline (type) were involved, except biological oceanography and the first year "general science" courses.

Type	No. of courses	Data from ...	prop'n
eng	*7*	*7*	*100%*
hydro	*4*	*4*	*100%*
geol	15	13	87%
envr	7	5	71%
pocgy	*6*	*4*	*67%*
geop	*9*	*6*	*67%*
atsc	*8*	*5*	*63%*
1xx	7	4	57%
bocgy	5	2	40%
Total	**68**	**50**	**74%**
QES -->	***34***	***26***	***76%***

Results: A separate page (PDF) summarizes results of this survey, characterizing the learning tactics that are experienced in courses for which data were obtained.

3.3.4 D. Computing in EOAS

Use of computing or computing resources in EOAS courses was determined by asking faculty to complete data for each course using a Google Sheet. Results are summarized as follows:

All faculty asked if computing resources are used. N = 39 out of 78 EOAS courses.		
	Uses computing resources	32
	Online content, NOT Canvas	10
	EOAS cpu labs (GIS, Python, etc.)	9
	OCESE dashboards (EOAS server)	11
Jupyter hubs	Students' laptops (2022 & planned)	10
Jupyter hubs	UBC's standard hub (2022)	2
Jupyter hubs	Google CoLab (2022)	1
Jupyter hubs	custom hub required	3
Jupyter hubs	EOAS-2i2c hub (planned)	6

Only 3 who are not already using computing indicated that they plan or hope to. This implies that demonstrations of successful examples are needed with details about costs to design, build, maintain and employ in courses.

Whether students are writing code can be seen from the QES course content data above. As of Fall 2022, fifteen courses claim to have students using Python (9), MatLab (4) or R (2).

3.4 Current EOSC 1xx courses

These are not on the curriculum dependency map because EOSC 1xx courses are essential per-requisites in any EOAS degree specialization. At 2020W they rarely included "quantitative" content, although by 2023W, this has evolved somewhat for EOSC 112. The Department is therefore considering a "quantitative" first year offering aimed at students with stronger math capabilities. This option is discussed on a separate QuEST project page.

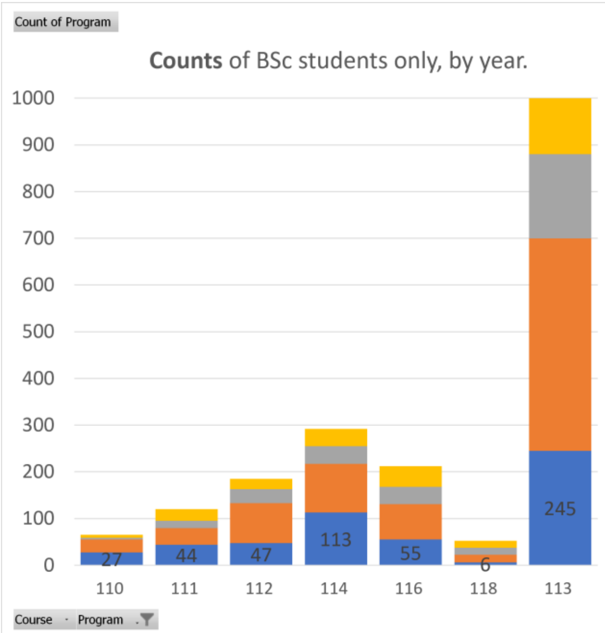
Are first year courses helping attract students into EOAS's quantitative degree programs? Is it true that they are not very rigorous? These questions are addressed using two sources.

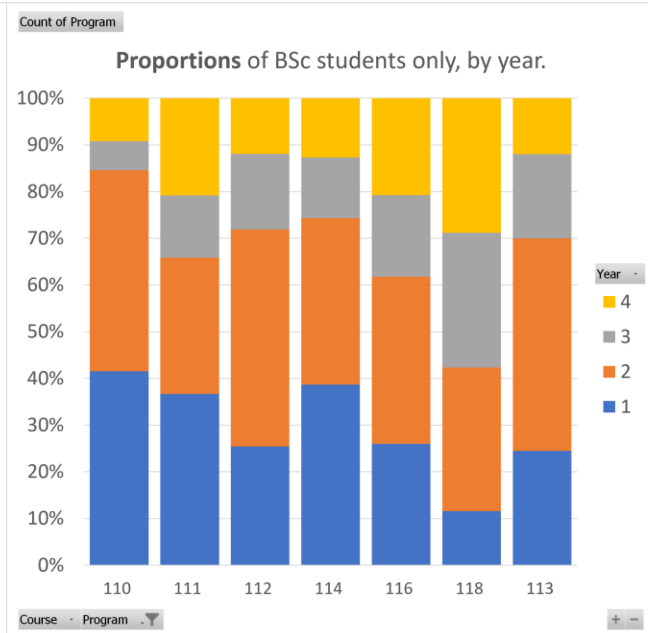
3.4.1 Influence of 1xx courses on degree choice

One question asked about the influence of first year courses on their decisions about what degree to pursue. Overall results of this survey are summarized here, and a briefer summary touching on demographics and influence on degree choice is provided here.

When asked "*Did any EOSC/ATSC 1xx course influence your choice to pursue an EOAS degree?*", 30-40% of Combined Majors, EOS Majors and Geology students answered "**yes**" while more than 90% for students in atmospheric sciences, geophysics and environmental sciences said "**no**".

Why might this be the case? First, no EOSC 1xx course is particularly quantitative. EOSC 112 and ATSC113 are perhaps a little more "rigorous" than others, but it is apparently easier to do well in these than some other EOSC 1xx courses (coloured table below). Second, few first year science students have the space in their first year course requirements to actually take an EOSC 1xx course. Enrollments of 1st yr students are mostly below 60 except for ATSC 113; blue bars in the figures here illustrating counts and proportions of enrollments in each EOSC/ATSC-1xx course.





3.4.2 Are EOSC/ATSC 1xx courses "rigorous"?

Demographics and grades by degree and year level were analyzed using class lists for the 2019-2020 teaching season. Results and comments, are in a separate report.

- More BSc students take EOSC 112 or ATSC 113 compared to other 11x courses. These are already more quantitative than the others, especially given adjustments to EOSC 112 since 2020.
- Courses where BSc students' grades are most elevated above BA students are EOSC 112, The Fluid Earth: Atmosphere and Ocean, and ATSC 113, Applied Meteorology.
- Other courses, EOAS 118, EOSC 114 and EOSC 110 have lower overall averages while the differential between BA and BSc students is between 6.5% and 7.5%. In the paleontology course EOSC 116, there is little difference between BA and BSc students.

	Compare BA and BSc average scores					
	averages		stdevs			avg
course	BA	BSC	BA	BSC		diff
116	81.7	82.8	15.1	14.1		1.1
111	90.4	92.9	7.4	9.2		2.5
118	78.6	85.2	10.4	11.3		6.6
114	72.3	79.5	12.6	11.6		7.2
110	73.6	80.9	11.3	11.5		7.3
113	84.6	94.2	15.4	8.5		9.6
112	74.0	87.2	15.2	12.1		13.2

- Averages are high in all these courses but perhaps that is acceptable since they are not "core" courses for any degree programs, and one "teaching goal" is to expose as many UBC students to Earth, Ocean and Atmospheric sciences as possible.

Further discussion about 100-level service courses is in the page about the proposed first year course targeting students interested in math, physics and computing. Marketing recommendations also include first year courses as part of the conversation.

3.5 GLOBAL DECLINE IN GEOSCIENCE STUDENTS

Global decline in *enrolments* is real (data below) but does it reflect a declining *societal need* for geoscience expertise? If the need is *not* declining why is enrolment declining?

NOTE: much of this page refers to "geoscience" because extracting similar information restricted to quantitative geosciences seems difficult or impossible.

Five countries: The recent Australian Geoscience Council (AGC) report on tertiary geoscience education by Cohen, 2022 provides a global perspective by comparing geoscience enrolments in Canada, USA, Australia, UK, and Italy (figure below). There seems to be a slight increase in geoscience enrolments only in Australia starting in 2020, while all other jurisdictions saw continued (although possibly slowing) decline.

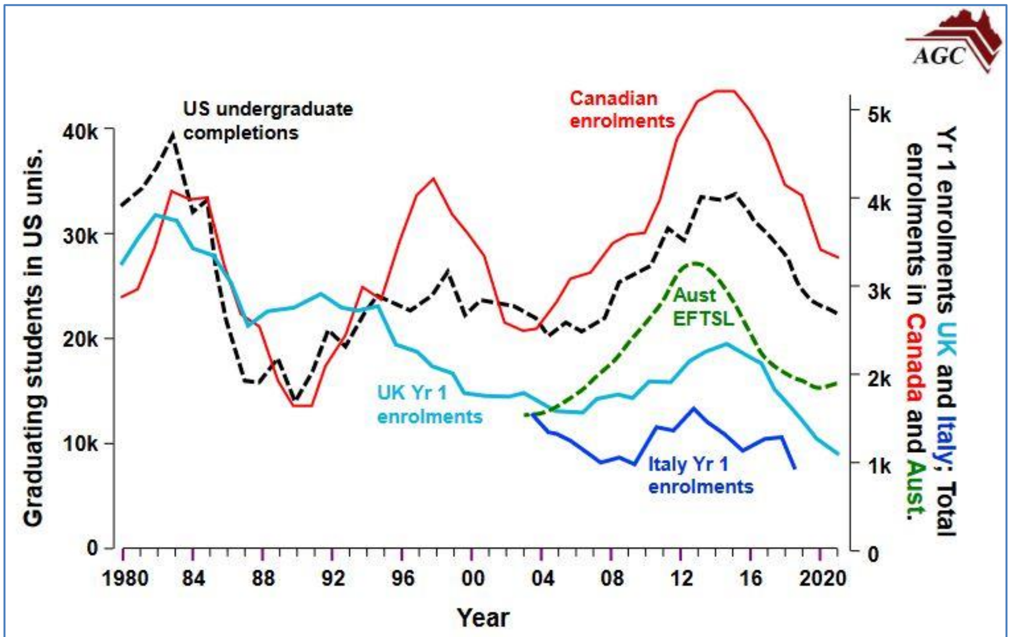
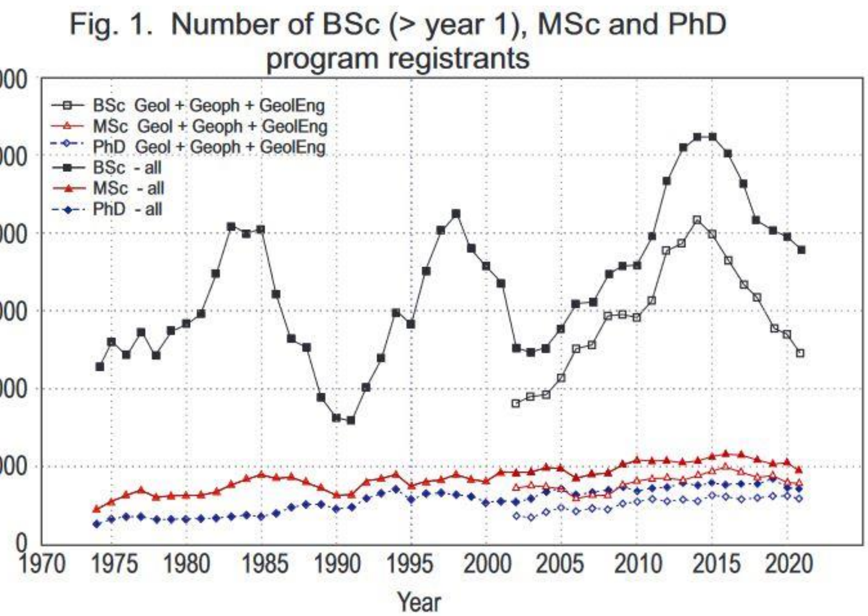


Figure 5. Comparisons of earth science enrolment trends in the US, UK, Canada, Italy and Australia[13].

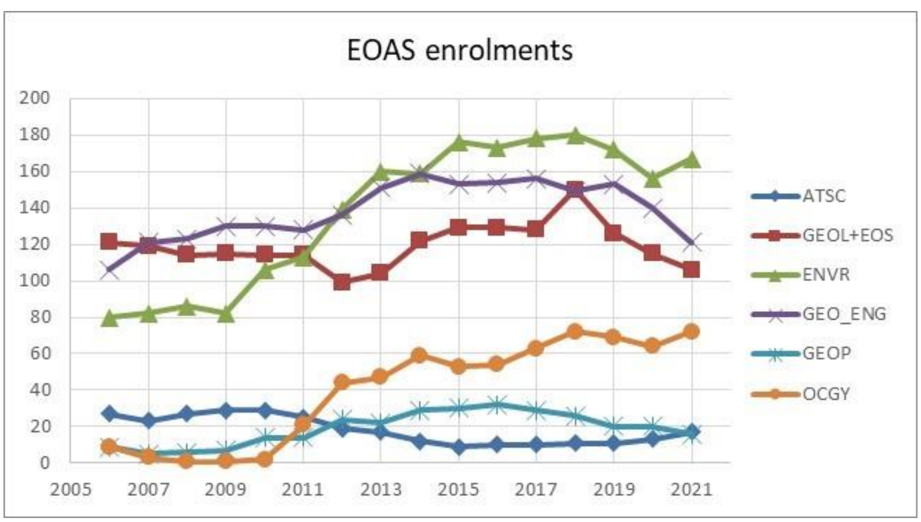
(The extensive AGC report also comments on "Content and curriculum", "Post graduate degrees and micro credentials" and suggests these three aspects represent opportunities for increased collaboration between industry and academe. The report also discusses changes in staffing, geosciences in K-12, and recruiting.)

The decline in geoscience enrolments continues in the USA into 2021, based on AGI's Status of Recent Geoscience Graduates, 2021, pg 10.

Canada: from conversations with peers, and from CCCESD data fro 1975 – 2021 it is evident that undergraduate enrolments in bachelors level programs across Canada continue to decline. Between 2000 and 2022 the number of faculty in Earth Science departments across Canada increased from ~500 to ~600 (figure 5 in CCCESD's data summary sheet).



EOAS: Do UBC's enrolments in EOAS degrees reflect this national trend? Yes, to some extent (next figure), but only for engineering, geology plus EOS and Geophysics, but not for oceanography (which includes biological ocgy), environmental sciences and atmospheric sciences which are all are experiencing increasing enrolments. For further enrolment and related data, see data from 2020 presented here. More specifically, enrolments have shrunk significantly in geophysics (32 students across all years in 2015 to 20 students in 2021) and atmospheric sciences (29 students in 2011 to 10 students in 2021) while oceanography & physics has always had small student numbers (~ 2) (Schoof, 2021).

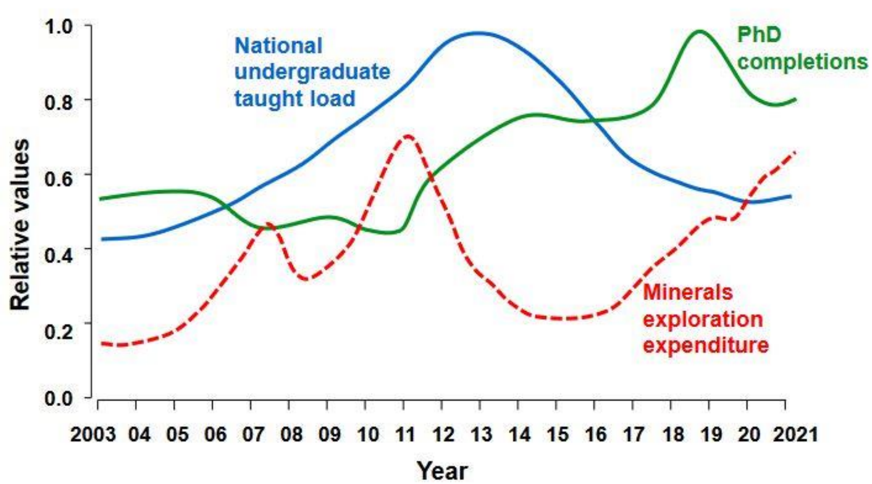


Why this global decline in geoscience enrolments? Quantitative geoscience graduates can be hired into many sectors in Canada. It is hard to aggregate information about global or national demand from all sectors, but especially in Canada and Australia, data related to resource exploration may provide some insight.

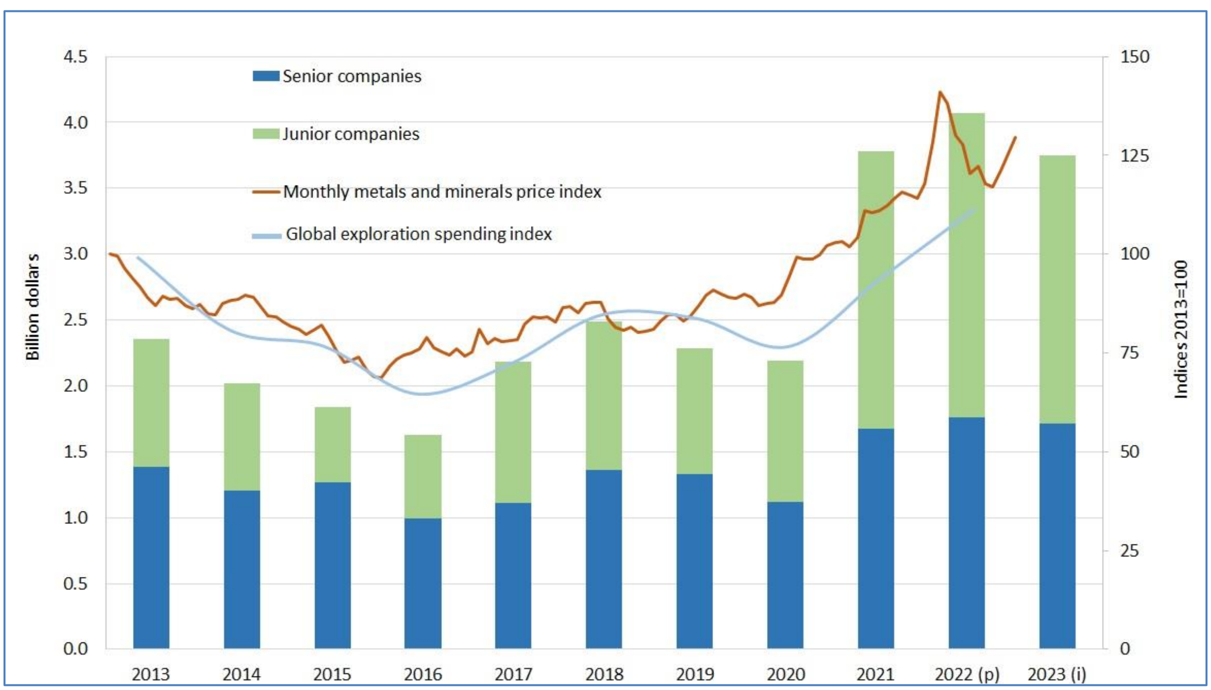
In Australia, the growth in mineral exploration expenditure may be contributing to an emerging increased interest in geoscience degrees. Cohen's AGC report presents data showing a lag of 5 years between the most recent trough in exploration spending and the most recent troughs in geoscience enrolments and PhD completions.

Snapshot of Geoscience in the Australian Tertiary Sector 2003–2021

	2007	2012	2017	2021
Undergraduate EFTSL	1998	3115	2127	1920
Honours graduations	156	235	183	118
PhD graduations	75	96	109	120
Academic staff (FTE)	354	418	482	398



Analogous data for Canada from the [Canadian Mineral Exploration Information Bulletin] (June 2023) suggests that the pattern of exploration spending in Canada (minerals, not oil/gas) was also lowest between 2015 and 2016, but the subsequent increase does not seem to be as uniform as in Australia (bars on the following graph).



Meanwhile, expenditures on geology and geophysics for oil and gas exploration in Canada have reached their lowest levels since 1977 (from data at the Canadian Association of Petroleum Producers or CAPP).

There may be a relationship in Australia between exploration industry spending and geoscience enrolments, albeit with a 5-yr lag, yet in Canada the picture seems more complicated. Canadian mineral exploration activity seems relatively strong in the past 2-3 years but oil & gas exploration activity that involves geology or geophysics remains slow. Meanwhile, geoscience enrolments across Canada continue to decline, while at UBC, enrolments in resource-related geosciences have declined recently (although apparently not as rapidly as national averages), while other disciplines taught in EOAS appear to be seeing increased enrolments.

3.6 Demand for geoscience & related expertise

3.6.1 Introduction

An April 2023 article in the Engineers and Geoscientists BC magazine "Innovation" is titled "Geoscientists: Are there enough to fill demand?"[2] It uses annual enrollments in geoscience degree programs and GIT or *Geoscientists In Training* statistics, with quotes from professionals and academics, to suggest that demand for geoscience expertise in BC currently outstrips supply. This apparent shortage of geoscientists and workers seems wide spread; see also Keane & Wilson, 2018, Keane, Gonzales & Robinson, 2021, Legault & Howe. 2021, Summa et al., 2017 (references).

3.6.2 Is high demand for STEM graduates a myth?

It generally seems that more students graduate with a BSc in STEM disciplines than there are positions in STEM occupations; 36.6% of all US workers with a BSc completed their degree in a STEM discipline while 14.4% of all US workers with a BSc degree are working in a STEM occupation (US Census Bureau, 2021). Data presented by the US National Science Board, 2022 are similar. The point was also discussed in the press over 10yrs ago – Yglesias, 2014. There are nuances to these sorts of data. For example medical disciplines are sometimes consider as STEM professions and sometimes not.

Further insights about current and recent shifts in BSc and MSc level hiring for 14 different employment sectors are illustrated as 7-year trends reproduced below. Sources for keeping up to date with the state of STEM workforce demand and education include:

1. US Census Bureau. "From College to Jobs: Pathways in STEM." Census.gov, May 2021. https://www.census.gov/library/visualizations/interactive/from-college-to-jobs-stem.html.
2. National Science Board. "The State of U.S. Science and Engineering 2022 | NSF – National Science Foundation," 2022. https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force.
3. IEEE Future of Workforce report by IEEE Industry Engagement Committee, via IEEE at https://www.computer.org/resources/future-of-workforce-report, and summarized For Forbes by T. Coughlin.

[2] Note: Much of this section refers to "geoscience" because extracting information restricted to quantitative geosciences seems difficult or impossible. However, some details from the geophysics community are provided.

3.6.3 General demand for geoscience

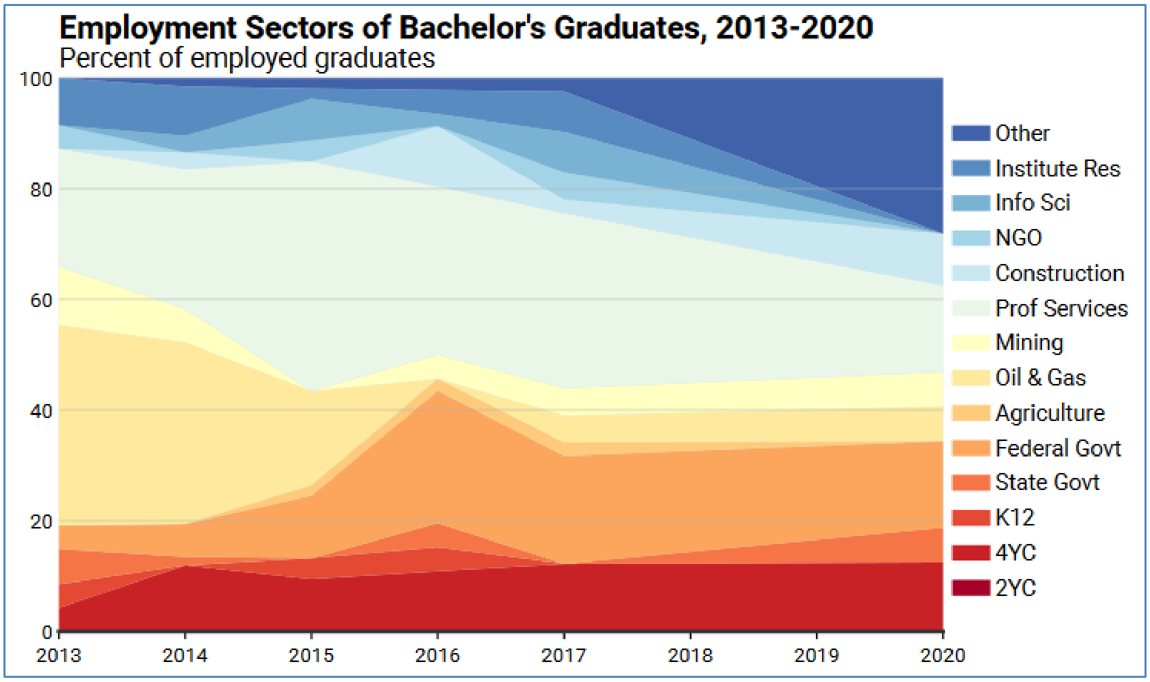
Based on a broad analysis of over 3600 geoscience job advertisements (Shafer 2023), there currently seems a reduced demand in geoscience occupations for BSc graduates with significant numerical and data science capabilities.

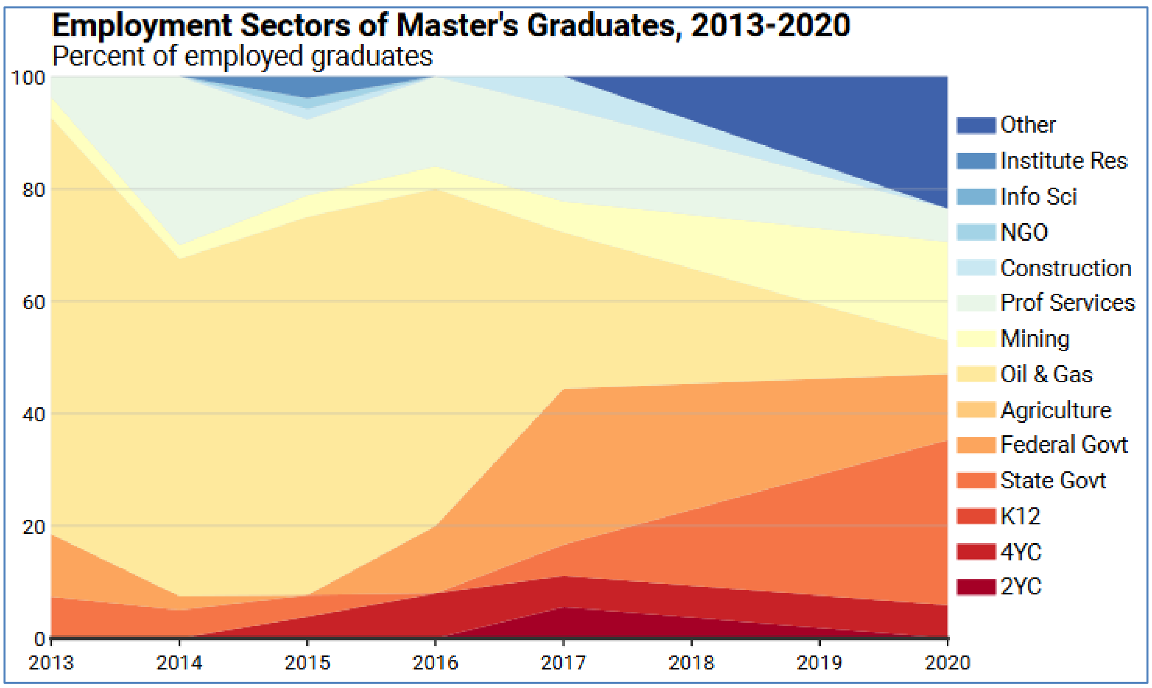
On the other hand, expectations expressed by academic and industry participants in an NSF-funded project that studied the future of geoscience education suggest a growing need for quantitatively capable workers across the geosciences (Mosher and Keane, 2021). Consistent with this general perspective are statements specific to the geophysics resource exploration industry, such as "*…the metals for the future are becoming harder to find, and we need to find and extract them with less impact. These factors demonstrate the growing need and bright future for geophysics in the mining industry*", quoted from Legault & Howe, 2021. The article mentioned above in the introduction paints a similarly optimistic future for minerals sector geoscientists more generally. Global expectations are also favorable:

- **Growth in exploration spending** and trickle down impacts on demand for geoscience expertise. "*Canada's exploration budgets rose 62%, or $799 million, year over year to $2.09 billion, a nine-year high*." quote from pg 13 of World Exploration Trends 2022, S&P Global Market Intelligence.
- "***Global exploration budgets rose 16% in 2022,*** *following a strong 34% rebound in 2021. After budgets fell 10% year over year to $8.35 billion in 2020 due to the COVID-19 shock, nonferrous global exploration budgets hit a nine-year high of $13.01 billion in 2022. The increase was driven by escalating interest in the global energy transition as part of global decarbonization efforts and by the ongoing pandemic recovery, and was supported by strong metals prices and healthy financing conditions. How would uncertainties in the global economy and opening "f China's economy shape the exploration sector in 2023? Download our report to learn more*". From S&P Global Market's World Exploration Trends, 2023.
- **Geophysics community in BC and Canada:** Based on two years of volunteering on the Board of Directors of both the BC Geophysical Society (as scholarship coordinator) and the KEGS Foundation, the applied geophysics community in Canada continues to be vibrant, and is optimistic about the future of the geophysics industry. As always, the number of new hires each year remains small, but their contributions locally, across Canada and around the world are critical in the resources, energy and geotechnical sectors. Canada has a history and reputation of innovation and excellence in geophysics, and this can only continue if the principal research institutions continue to produce graduates with the diverse capabilities unique to applied geophysics.
- **The demand for geophysical expertise continues to diversify** is illustrated by the newly published textbook "Engineering Geophysics", 2023, edited By Anna Bondo Medhus, Lone Klinkby. It includes 12 chapters of explanations about how the range of methods can be applied in geotechnical settings, but more impressively, there are 48 different case histories presented, illustrating a huge range of applications that contribute unique information to important societal challenges.

Of course these minerals and geotechnical sector perspectives may not say much about demand for BSc graduates from other disciplines such as atmospheric sciences or physical oceanography. However, growth in resource sectors includes growth in – or perhaps more correctly changes to – the energy sectors and needs for quantitatively capable professionals with a broad demand for professionals capable of solving quantitative problems involving the Earth and its atmosphere, its oceans and its environments.

The AGI's Status of Recent Geoscience Graduates, 2021 provides many details about enrollments, demographics, curriculum, skills and employment of geoscientists. The 7-yr trends in 14 employment sectors for BSc and MSc graduates are particularly interesting (section 4.13 of their report). Figures from pages 68 and 69 reproduced here illustrate, although details should be explored in that status report.





For roughly annual updates on many facets of geoscience professions, the **AGI's Geoscience Currents resource collection** provides snapshots of professionals, in-depth case studies of how geoscience is applied, factsheets with rigorous introductions to a range of geoscience topics, workforce trends, and career paths; well worth exploring periodically.

Arguments can be made regarding the importance to society of more visible, accessible and rigorous geoscience educational occupations, including increasing quantitative components across the spectrum of geoscience. Chapter 1, "A call to action", in **Mosher and Keen, 2021**, includes 11 "key outcomes" of the NSF-funded "*Future of Undergraduate Geoscience Education*" initiative, one of which is "*Growing demand for* *geoscientists requires departments and programs to recruit, retain, and promote the success of undergraduate geoscience majors across a broad spectrum of society.*"

Other timely sources of geoscience workforce analyses include:

- Shafer, et.al., 2022: "**Analysis of Skills Sought by Employers of Bachelors-Level Geoscientists.**"
- **Are we teaching what students need**? This was asked and analyzed by Viskupic et al., 2021, "*Comparing Desired Workforce Skills and Reported Teaching Practices to Model Students' Experiences in Undergraduate Geoscience Programs*".
- Four statements summarizing current (2020-2023) geoscience workforce context, from Viskupic and Egger, workshop 2023:
    - *"Bachelor-level geoscientists represent the majority of the current geoscience workforce (U.S. Bureau of Labor Statistics, 2022)."*
    - *"Bachelor-level positions are forecast to increase by as much as 10% (NCSES, 2021)."*
    - *"Geoscience must do better at attracting and supporting students because geoscience is currently one of the least diverse STEM fields (Bernard & Cooperdock, 2020; Gonzales & Keane, 2020)"*
    - *"Students (and research-oriented faculty?) have little awareness of career opportunities, and of what skills and abilities are needed in the workforce (Viskupic et al., 2022)"*
- AGU's EOS topic "Education and careers", including the annual **Career Issue**: see professional profiles (mostly scientists) in issues 2021, 2022, 2023.

3.6.4 Specifics regarding the "niche" that is QES

Several colleagues at peer institutions suggested that they anticipate continued migration away from QES programs by making comments like "*other quantitative programs like engineering are more practical*" or "*quantitative students are turning to the information economy*". However, perhaps this "gloomy" perspective might serve as inspiration for creative adjustment to the way earth science disciplines are offered to prospective undergraduate students? Quantitative specialists in the geoscience professions may be a small proportion of the total, but all sub-disciplines are expected to become increasingly dependent upon skills related to data assessment, management & analysis, and numerical modelling of physical and chemical processes to help anticipate, plan, design, and manage society's needs and impacts on the Earth. Three indicators that could be taken as incentive to reinvigorate quantitative BSc Earth Science degree programs are:

1. Optimism for long-term growth and evolution in the **resource and energy sectors**, mentioned above.
2. From Canada's **Budget 2023**: one of three highlights is "growing a green economy", for which eight priorities are listed: 1. **Electrification**, 2. **Clean Energy**, 3. Clean Manufacturing, 4. Emissions Reduction, 5. **Critical Minerals**, 6. **Infrastructure**, 7. Electric Vehicle & Batteries, 8. **Major Projects**. Items 1, 2, 5, 6 and 8 are all directly dependent upon quantitative Earth science expertise.
3. **"Future of Workforce"** from the IEEE Computing Society's Oct 2022 Report (51 slides) and Exec summary (4 slides – graphical and succinct). This is extensive, global, and compiled over 1.5 years. Download or see reaction at Forbes magazine (Coughlin, 2022). This does not target geosciences, but implications are relevant graduates who can aspire to careers in a wide spectrum of occupations that require capable quantitative and data science professionals.

It could be argued that B.Sc. degree programs are more about learning fundamentals and maturing as a young adult and less about "job training". However, most students embark on degree programs in order to become employed in rewarding and meaningful occupations. In EOAS, only 18% of 85 surveyed students said they planned to pursue further education beyond their BSc; [Jolly, 2020](). Therefore, educational programs need to be agile and responsive to changes in the sectors that will hire graduating students. This is one of the arguments for diversifying the more traditional, "siloed" or constrained degree specializations. And "diversifying" is needed both in terms of disciplinary and interdisciplinary diversity and in terms of the human diversity of students and professionals. As mentioned above, and discussed in the Nature – Geoscience article (Bernard & Cooperdock, 2020), the geosciences generally are found to be one of the least diverse STEM fields. Oceanographers Johnson et al., 2016 discuss strategies for increasing diversity in ocean science workforce, thus "*cultivating future global ocean science leaders who collaborate effectively to make discoveries, achieve solutions, and develop technologies*". EOAS could aspire to be a leader in establishing effective, diverse and rigorous undergraduate programs in quantitative Earth sciences.

3.6.5 Conclusion

Perhaps one implication of all this discussion is that quantitative Earth science qualifications may continue as a "niche" degree option, probably with potential for some growth, especially as students recognize the need for rigorous background prior to gaining additional, specialized qualification at the graduate levels. However, if quantitative degrees could involve a greater diversity of students (both in terms of demographics and disciplinary interests) there is reason to be optimistic that rigorous and relevant undergraduate degrees in quantitative Earth sciences that transcend traditional silos can attract sustainable numbers of students.

3.7 DEPARTMENTAL CONTEXT

3.7.1 EOAS perspectives

The Department's current "state" is best articulated by referring to the most recent strategic plan and stated aspirations from departmental meetings and retreats.

The EOAS Department's 2021 strategic plan (executive summary) provides a snapshot of aspirations based on deliberations within the department, it's history, and anticipated priorities of incoming new faculty. Of particular relevance to the QuEST project:

>>Departmental aspirations are predicated on the facts that (a) Earth sciences are rapidly evolving due to new measurement, analysis, computational and interpretation techniques, and (b) understanding the complexity of Earth's System and human influences demands inter-disciplinary, multidisciplinary and collaborative scientists and professionals. EOAS faculty, staff and students are motivated by the challenges facing societies, and inspired by a curiosity to understand the natural world. Aspirations expressed included building on existing core strengths, fostering collaborations in both teaching and research, and engaging with civil society to bring data- and science-based solutions to all the challenges of living safely, sustainably and equitably on our planet.

>>Mathematical and computational methods are a particular strength within EOAS. They are a cornerstone of research and learning needed to address urgent challenges such as climate change, geohazards, and mineral, water and renewable energy resources. Enhancing the department's world-class teaching programs is one of several primary goals, with quantitative and computational methods for data analysis and modelling a key component for all degree programs. Another goal is to reach beyond our standard degree programs to provide opportunities targeting both public and professional audiences, with certificate programs for professional learning and outreach activities for public and K-12 audiences.

Quantitative aspects of our disciplines do need to be visible and comprehensible appropriately for the targeted audience.

Aspirations & commitments expressed at the EOAS Dep't retreat, May 2022, include:

- OCESE, QuEST and EaSIEL are key **on-going projects** that will continue into the current year and likely beyond. These represent good opportunities for people to collaborate in teaching across EOAS disciplines.
- We will launch a new **3-year u-grad teaching plan** next year.
- We need to consider broader implications of a **potential expansion of environmental science education** (and research) across the Faculty of Science, and EOAS's key role in that.
- We should consider **how might we give EOAS students a broader understanding of the societal implications of Earth Sciences**, while still providing them with appropriate technical knowledge.
- Some ideas were discussed regarding ways to help students re-connect in a (hopefully) post-COVID learning environment.

Strengths, or "identify" of the Department, based on paired interviews completed in early 2023. Thirty two research or teaching faculty were contacted and 17 participated. The three most agreed upon characteristics are:

1. The department is unusually multi-disciplinary in terms of (a) the range and types of quantitative science used and taught and (b) styles of academic "upbringing".
2. The perceived scope of "quantitative Earth science" varies according to discipline, but all agree that data science is key – and growing – across specializations.
3. The Earth sciences can be a particularly meaningful, important and inspiring context in which to earn a science degree, yet the opportunities are poorly recognized by prospective students, their families, and advisors who help students decide on post-secondary options.

The unusual **diversity of EOAS** could be considered as both a challenge and an opportunity.
>>The challenge is articulated by a quote from Kwok, 2018, "*Courses should be designed for the benefit of students, not the convenience of the instructors. Some courses are in the syllabus because they reflect the research specialties of individual faculty members, which may not be essential to a particular major.*" EOAS needs to agree on fundamental capabilities desirable in graduates with and "Earth sciences" degree, and choose program objectives that ALL (or at least most) faculty members could contribute towards.
>>The opportunity is that EOAS has a unique opportunity to offer students a truly interdisciplinary perspective on quantitative nature of Earth sciences, a perspective that could be argued as especially relevant to society today and moving forwards.

The geophysics community in BC and across Canada continues to be vibrant and UBC's contributions continue to be important, both in terms of graduates and research. A one-day "open-house" event celebrating the UBC Geophysical Inversion Facility in November 2022 attracted over 40 participants from local geophysical industry and academic communities. The attended to celebrate 30 years of contributions to applied geophysics from the GIF group, to welcome the new incoming director, Prof. Lindsey Heagy, and to hear about current and future directions of research.

The number of undergraduates in the geophysics program is “low” but the potential for increasing the number of quantitative students in geophysics and related programs is at least as strong as any institution in Canada. The Department would be missing opportunities for growth if these sector was allowed to fade.

Student perspectives from the survey of 4th year EOAS students in 2020 (Jolley, 2020) support the fact that EOAS options are rather “invisible” to potential or prospective students. Sadly, the majority of respondents identified the UBC Calendar as the place they first learned of the specialization they eventually pursued. Even the EOSC 1xx courses were not commonly as influencing decisions. This is a widely held perspective as other institutions and colleagues commonly agree that geosciences are under-represented as inspiring degree options. These types of data speak mainly to the need for marketing quantitative degree opportunities rather than saying something useful about curriculum.

A “bottom line” question: Can EOAS establish principles underlying science curricula in EOAS? Balancing professional and scientific priorities is challenging, but EOAS has great diversity across scientific and professional perspectives.

3.7.2 Faculty of Science and UBC Strategic Plans

The **Faculty of science strategic plan** includes four core areas with objectives. Relevant to the QuEST project objectives is the Education core area, involving three strategies. These are less about discipline-specific issues, and more about ensuring equitable perspectives on subject matter and access to education, and continued excellence in teaching and learning practices. Specifically the three strate

- Progression in the use of evidence-based approaches to teaching and learning.
- Cultural competency, equity, diversity, and inclusion through curriculum and pedagogy.
- Programming and mechanisms that reinforce a student-centered experience.

The **Data Science Curriculum Group 2019 Report and Recommendations** for the Faculty of Science, prepared between 2018 & 2019, are also relevant. The QuEST project was initiated partly in response this report which stated: “*…current and future graduates need skills to organize, interact with and extract meaning from data.* [These skills] *… are applicable to a wide and expanding range of career paths and will open future opportunities for UBC students, as well as contribute to a data-literate citizenry.”*

From UBC's strategic plan, the "Transformative Learning" component has several assumptions, summarized as follows:

- "*A rapidly diversifying economy, social context and job market requires a different kind of education — one with greater focus on transferable skills, such as critical thinking, collaboration and communication, and one that promotes and supports continuous learning.*"
- Students need to be considered as co-creators of their education.
- Program should be redesigned around competencies; the development of problem-solving experiences; technology-enabled learning; and continued growth in work-integrated education.

These are the five strategies for addressing "transformative learning", each directly targeted in QuEST project recommendations:

1. **Education Renewal**: Facilitate sustained program renewal and improvements in teaching effectiveness.
2. **Program Redesign**: Reframe undergraduate academic program design in terms of learning outcomes and competencies.
3. **Practical Learning**: Expand experiential, work-integrated and extended learning opportunities for students, faculty, staff and alumni.
4. **Interdisciplinary Education:** Facilitate the development of integrative, problem-focussed learning.
5. **Student Experience:** Strengthen undergraduate and graduate student communities and experience.

3.8 EARLY PRIORITIES

3.8.1 Introduction

This page summarizes EOAS faculty discussions about quantitative programs and courses at spring retreats in 2019 & 2020 and using emails or shared documents during summer 2020. For details see pages "Priorities, summer 2020" and "Concepts, tools and programs; early ideas".

3.8.2 What kinds of students to target?

EOAS faculty who teach geophysics, atmospheric sciences and physical oceanography aspire to attract students with similar qualifications as those entering physics degrees. The general consensus seems to be that it should be possible to attract 15-20 such students into Quantitative Earth Science (QES) degrees. It was also suggested that a few students who have chosen the ENSC (Environmental Sciences) specialization may fit this profile.

A question often discussed is whether students would be best served by offering curriculum that prepares them for traditional QES career paths (eg. geophysics) or whether a more general quantitatively oriented curriculum is more appropriate. Some argue that "*university education is not about setting up students for specific careers*" while others feel a responsibility to "*prepared students to enter specific career paths upon graduation*". The optimal curriculum is probably some combination. Students will be attracted to programs that clearly prepare them for attractive opportunities upon graduation, yet they do need to be well-prepared with foundational knowledge, skills and capabilities.

3.8.3 Possible changes to EOAS

Faculty in EOAS have expressed a desire to "revamp" quantitative degree programs to better reflect the broad perception of "geophysics" as including all the disciplines addressed by the AGU (American Geophysical Union). Such a program would graduate students well grounded in Earth Science, with some choice in specialization (solid earth, fluid earth, hydrology / hydrogeology, climate & Earth systems science) who are (age-appropriately) fluent in math (including PDEs and linear algebra), scientific computing, data analysis, and the physical foundations including mechanics & continuum mechanics, thermodynamics, electromagnetism and fluid dynamics.

More specifically, ideas that were discussed include the following (more details are on the "Priorities, summer 2020" page).

- Making gradual changes to existing courses is probably the most efficient approach to curricular reform, although new faculty will likely introduce new courses to coincide with their expertise.
- Adjusting or creating courses should be done as part of a well-articulated Departmental plan rather than making ad-hoc changes in isolation of the Department's context.
- Proactive engagement with the (evolving) Environmental Sciences program was considered an important opportunity for QES curricular renewal.
- There is interest in exploring options for partnering with physics, math and computer science to create new (or to market existing) joint, minor, or other degree options. Also, students would benefit from more proactive advising to help them identify existing opportunities.
- Finding the right mix of faculty members to contribute towards rejuvenating QES curricula was recognized as challenging. A larger team would be unwieldy, yet allowing decisions to be made by too few individuals is also not optimal. The time and energy expected is perceived as daunting, leaving many unwilling to commit. Departmental support such as teaching or committee duty buy-outs will be important.
- The challenge of balancing fixed versus flexible curriculum was also discussed. Individuals may want to exercise their academic freedom to teach what they want, yet some components of a degree's curriculum do need to be fixed. In reality a balance can normally be found, but it does help to be explicit about how this balance works in each course, and across a degree's curriculum.
- The potential for "rebranding" quantitative earth science degree specializations as a unified "subject", akin to the way the American Geophysical Union (AGU) which considers all physical Earth sciences at "geophysics". (AGU includes 25 sections all dedicated to fostering scientific discussion and collaboration rather than focusing on concerns of industry.)

3.8.4 Outreach, recruiting, marketing and a new first year QES course

Actively attracting students (i.e. "marketing" the QES programs) was considered to be a priority by most participants in discussions. Many options are detailed in the Marketing section of QuEST documentation. Here are some initial ideas suggested in the early discusses of 2019 & 2020.

- Instigate outreach activities targeting high school students, teachers and advisors.
- Rebuild all content on the Department's and UBC's websites that describe the strengths and benefits of pursuing QES degrees at UBC, and emphasize the opportunities available to students graduating with a BSc in QES disciplines.
- Enhance the way students are advised, especially regarding the way their QES degree specializations relate to the world of work and the challenges facing society.
- Increase the instances of incorporating work-related contexts into QES courses, especially those that can be rather "theoretical" in nature.
- Make QES degree opportunities more visible to first year science students at times that coincide with when they make decisions about their specializations.

- Improve the sense of community among QES undergraduates, graduate students and faculty.

Developing a new first year course that will inspire and challenge students keen on physics, math and computing is considered a priority by several faculty members. While it is true that such a project involves bureaucratic, "political" and practical challenges, interest appears to remain strong. Details of ideas to date are summarized on a separate page in QuEST documentation. In particular, a focus is needed that is both representative of the Department's expertise and inspiring to prospective students. The most widely discussed option is a course that might be called something like "Introductory Climate Physics". To consider include:

- how to be appropriately "rigorous" while avoiding the need to teach mathematical or physical fundamentals;
- how to be both "inspirational" and non-trivial;
- a sustainable teaching model is needed that will ensure consistency and motivate EOAS faculty to want to contribute;
- background "market research" will be needed to clarify potential enrollments and ongoing "marketing activity" will be needed to attract appropriate students;
- use of UBC's curricular development support (CTLT) should be engaged to help ensure best practices are used for instructional design.

3.8.5 Possible program learning objectives (PLOs)

An initial attempt was made to articulate a single set of PLOs for QES specializations. These are on the "Concepts, tools and programs; early ideas" page, but they would benefit from refinement, perhaps by synthesizing from the existing PLOs for the three QES degrees, and consideration of EOAS service course PLOs.

3.8.6 Concepts to be learned

The table below summarizes concepts that several faculty members listed as priorities for any quantitative Earth sciences degree.

Math and geophysics were emphasized but few "geoscience" concepts were listed in the initial discussion. However, the Earth system context is what makes a QES degree distinct from math or physics degrees. Therefore, thinking styles that are uniquely "geoscientific" should be modeled and practiced. This can done by weaving geoscience contexts into existing courses, but it needs to be explicit, by design, and sufficient opportunities to practice these skills and assess student progress.

Most concepts in this table are already taught – see the "Current EOAS course content" page. Also, not all concepts would be required to complete a QES degree, and they are not meant to map one to one onto individual courses.

Fundamental concepts	Earth-science concepts	Methods, tools, strategies
• conservation laws, mechanics, thermodynamics • equations of state, constitutive laws • waves (how? to what degree of sophistication?) • diffusion, damping, advection	• continuum mechanics (plus basic classical mechanics) • fluids, solids, porous media • GFD	• ODEs and PDEs (initial and boundary value problems) • scaling & dimensional analysis • systematic model simplification, heuristic lumped (box) models • dynamical systems

• signals and noise • forcing and feedback, stability, bifurcation • scientific hypothesis testing by both experimentation and observation • simulation and prediction using empirical / statistical models	• convection in a variety of settings • hydrology & hydrogeology • seismic wave propagation • potential fields: gravity, magnetics, EM in context • climate physics	• numerical methods for deterministic models, discretization methods • inverse models • spectral analysis, signal analysis • data analysis, image analysis • statistics • machine learning etc.

3.8.7 Course ideas

Several concrete suggestions were made for new or updated courses that would be taught by specific faculty members. Suggestions included climate physics and/or modeling, image processing, and applied geophysics & related processing and inversion. There are certainly other ideas not yet explored.

3.8.8 A proposed program outline

Some minor adjustments were made to the geophysics curriculum just prior to the COVID pandemic. Several adjustments were consistent with a geophysics program sketched out by one faculty member and discussed with colleagues. The discipline of "geophysics" was defined to be consistent with the way the American Geophysical Union (AGU) defines it. The "common threads" include:

- Mathematics: calculus (including vector calculus), linear algebra & Ordinary/Partial differential equations
- Physics: mechanics, waves, continuum mechanics, fluid flow, electrodynamics
- Computing: signal and image processing, problem-solving by programing, data science including visualization, AI and ML (not "how computers work")
- Field and observational measurement techniques and corresponding data wrangling.

This should (but did not) include exposure to the unique styles of thinking associated with understanding how Earth works, including geology, hydrogeology, climate science and so on. Geoscience thinking has unique aspects that QES specialists should encounter so they can contribute effectively in the teams they will work with.

3.9 DESIRABLE SKILLS

This page is the summary section from the complete report.

This section is about desirable **skills**. The recommendations sections are about desirable **tactics** for attaining (and fostering) those skills.

NOTE: when the terms such as "Earth sciences" or "geoscience" are used, they are meant to encompass all geologic, atmospheric, ocean, environment and climate sciences.

Capabilities and attributes that students **should** be able to demonstrate upon graduation from a quantitatively oriented Earth science (QES) program are described and discussed. This is not about the **current** QES curriculum in the department of EOAS. That is described on the current QES course content page. Options and preferences are based on input from interviews, surveys and discussions with EOAS faculty and students, from peers and peer institutions, and from literature about career preparation from academic and employer perspectives.

The QuEST project focuses on quantitative earth sciences, and the desirable skills here reflect that. However, the "employability" of a student depends at least as much on abilities and attributes that are not unique to a discipline. Saunders and Zuzel, 2010, quote a useful definition of employability as "*a set of achievements – skills, understandings and personal attributes – that make graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy*." Usher, 2022, discusses some aspects of why it seems difficult for institutions to anticipate market demand – i.e. to define how best to prepare society's future professionals. Four basic (and perhaps obvious) aspects are (a) the future is hard to predict, (b) companies, governments and universities or colleges do not have the same priorities, (c) companies are precise about skills they want when hiring, but most of those skills arise from *experience* not *academic learning* and (d) academics (and institutions) are slow and sometimes reticent to change. Therefore, the majority of desirable skills (with a few exceptions) are considered "generic" rather than targeting specific careers or disciplines.

A slightly more "academic" articulation of forward-looking goals for a university-based undergraduate education is offered by Kwok, 2018 (short, clear, and well worth reading): "*A lot of factual information is available on the Internet, and artificial intelligence is making certain occupations obsolete. It is therefore much more important to give our students fundamentals that will stay with them for the rest of their lives. These essential tools include language skills such as comprehension, expression, and communication, as well as quantitative skills such as analysis, seeing hidden patterns, identifying variables, and formulating solutions to problems.*" Note that "*fundamental skills*" here does not refer to "basic theory of a discipline" – it means well-educated, careful, creative and clear ways of thinking.

To reflect the distinction between discipline specific capabilities and the more general characteristics of highly employable graduates, desirable skills identified below are organized into three main categories; (a) knowledge, skills and attitudes that are essentially quantitative (i.e. math, physics and computation), (b) those that are unique to the geosciences, and (c) capabilities associated with a person's readiness to enter the workforce or advanced education.

Preparing highly employable graduates is not only a responsibility of the Department, but successful graduates are also important from the recruiting or "marketing" perspective.

3.9.1 Regarding quantitative capabilities

One persistent theme is the importance of "higher-level" aspects of QES learning, i.e. the need to nurture critical thinking involving quantitative and data-oriented information. It takes time and guided practice to gain the necessary maturity to make reliable decisions and judgements based on physics, data sets, and mathematical models.

Quantitative "topics" are easy to list and they seem relatively consistent across QES degree programs. However, rather than listing topics like "ODEs" or "linear algebra", the important concepts would be more usefully described in terms of the scope, context and expected level of mastery. The department's research expertise will inform these contexts and those chosen should span the degree specializations, however, students also need to experience settings that reflect the broader world of work.

Computing should be integrated throughout quantitative courses and curriculum. This reflects the growing recognition of computing as a fundamental form of "literacy" across professions (e.g. Guzdial, 2019). A balance is needed between the development of coding skills versus quantitative knowledge that uses computing codes. These two "goals" are not the same and mixing them can compromise success.

AI/ML (including generative AI) is rapidly emerging as a necessary component of thinking across the STEM disciplines. Forward looking curriculum must include opportunities for students to gain mature and well-informed capabilities involving AI.

Sources that consider desirable skills more generally for geoscience graduates are not focused on smaller quantitative programs, but they do remind us that basic numerical capabilities should not be lost in the advanced math; capabilities such as data visualization, managing uncertainty, informed use of statistics, wrangling large and/or public data sets, etc.

Collected quantitative capabilities

To be selected or adjusted and specified with contexts & levels of mastery, appropriately for the specific degree specialization.

- Pervasive *critical quantitative thinking* involving numerical, model-based and data-oriented information in Earth science settings.
- Basic numerical capabilities: fluent algebra & trig, plotting, uncertainty, data organizing, spreadsheet uses.
- Fundamental math including calculus, ODEs & PDEs, numerical methods – BUT in context.
- Specialized math including signals and spectra, image analysis, inversion, modelling.
- Statistics and statistical thinking.
- Fundamental physics, including mechanics, waves, thermodynamics, continuum mechanics, E&M, measurement, instrumentation.
- Specialized physics: atmospheric physics, geophysical fluid dynamics, potential fields, waves of all types.
- Fundamental computing including programming and code-based problem solving, integrated throughout curriculum.
- Data science, including data access, wrangling, visualization, quality assessment.
- Pros, cons and ways of applying artificial intelligence and machine learning, including potential and limitations of Generative AI.

3.9.2 Capabilities unique to the geosciences

Specific geoscience-based capabilities are important because it is the Earth science context that distinguishes an EOAS quantitative degree from a physics, math or computer science degree. Research faculty in quantitative disciplines naturally focus on their own important methods and concepts. But they also tend to gloss over the unique aspects of geoscience and how geoscientists think when hypothesis testing or problem solving. Increasing the attention paid to field, lab, mapping (especially GIS), observational and related skills was considered desirable by employers. Researchers who interact with non-academics also identified these priorities, but purely academic scientists were less likely to mention them. Students also highlight their desire for more "application oriented" settings or contexts while practicing with fundamental concepts.

The distinction between important "geoscience concepts" and important "geoscience skills" was made by the most comprehensive evaluation of current and future geoscience education (Mosher and Keane, 2021). For example, "concepts" include **deep time, climate change, Earth materials, natural hazards** and others, while "skills" include **spatial and temporal interpretation, working with uncertainty, integrating disparate data,** and others. This distinction helps clarify how the more quantitative capabilities should be expressed. On their resumes, students need to be able to demonstrate "capabilities" rather than simply listing "concepts encountered".

One category of capabilities rarely considered in curriculum discussions is the so called "*societal relevance skills*". These are important for preventing the sense of "isolated knowledge" that young students experience when learning (for example) basic calculus from abstract mathematical perspectives. When students can articulate the personal and societal relevance of their learning, they are more motivated and consequently more successful.

Collected geoscience capabilities

To be selected or adjusted and specified with contexts & levels of mastery, appropriately for the specific degree specialization.

- Fundamental geoscience: deep time, rates of geological, atmospheric and ocean processes, scales of influence, spatial information, observational nature of geoscience.
- Specifics: tectonics, geological materials, resources, hazards, geomorphology, hydrogeology, ocean behavior, basic meteorology and climatology.
- Field, lab, GIS and observational skills (but not necessarily "specialized" software).
- Instrumentation, measurement, data management and analysis, where relevant, for geophysical, atmospheric, oceanographic and hydrological work.
- Multi-disciplinary nature of geoscience (physics, chemistry, biology, geology).
- Inter-disciplinary nature of the Earth, ocean, atmospheric, and environmental sciences.
- Societal relevance of geoscience topics, ideally based on engagement with civic or commercial sectors.

3.9.3 Career-readiness capabilities

Note that interviews were conducted with EOAS faculty to ask specifically about **tactics** (not skills) they consider effective at helping students prepare for post graduation opportunities. The full report is revealing about different tactics considered important by faculty with different backgrounds and experiences with non-academic sectors. More is discussed in the recommendations section on Career Preparation, and details are in the full report.

Career-readiness capabilities are those aspects of "maturity" sometimes called soft skills, work-place competencies, or something similar. Faculty know these are important and many were mentioned or implied during interviews, including communication skills, teamwork, reliable synthesis of information, and the ability to relate learning to societal and work-place priorities. Conversations focused on tactics for supporting student development rather than articulating the required capabilities. Students certainly benefit from these activities but more clarity about exactly what capabilities are targeted – and why – would increase motivation and help them relate their studies to future occupations.

From the perspective of employers, relevant work experience is highly desirable. This is not a "skill" or "capability" but many employers believe that the "soft skills" and "work-oriented attitudes" can best be obtained in the workplace rather than by studying at school. Unfortunately, finding a first job that is relevant is increasingly difficult. Ng, 2023, refers to this problem as "*experience inflation*". Employers also expect students to be able to set appropriate expectations about work habits and the commercial and business aspects of employment. Can degree programs provide relevant experiences without compromising academic priorities? Probably, but a little creativity is needed. Consulting with colleagues, instructional designers and career preparation experts will help weave relevant work-related settings into learning activities. In addition, employers want examples of students applying fundamentals in applied situations, and evidence of a student's experience in both team-working and leadership roles.

Collected capabilities supporting career & post-graduate readiness

To be selected or adjusted and specified with contexts & levels of mastery, appropriately for the specific degree specialization.

- Logical and deliberate approaches to problem solving including scientific design and hypothesis testing by observation or experimentation.
- Develop a sense of curiosity and acquire the confidence to ask questions and challenge assumptions.
- Synthesis of diverse information & use of public & proprietary literature.
- Ability to relate learning to societal and work-place priorities.
- Cooperative aptitudes regarding teams, leadership and self-directed working situations.
- Communication skills, especially written and oral.
- Professionalism regarding technical, commercial, business and personal aspects of the workplace.
- Time or project management tactics practiced (for example) during capstone or project activities.
- Awareness of the importance of ethics, budgets, balancing needs of clients and employers.
- Personal skills associated with appropriate behavior regarding justice, equity, diversity and inclusion.
- Career and self-development skills including life-long learning abilities and habits.
- Ability to plan for career progress and establish & maintain a network of colleagues and peers to support professional or academic development.
- Tailor a resume or other expression of personal abilities to suit any relevant job, study or other opportunity.

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4 RECOMMENDATIONS

4.1 INTRODUCTION TO RECOMMENDATIONS

4.1.1 Introduction

Suggested tactics and actions – aimed at enhancing QES courses and the development of uniquely qualified QES graduates – have been organized based on their scope of implementation. The sections are:

1. Enhancing courses: actions that can be applied in a single course or sequence of courses.
2. Enhancing existing degrees: actions for adjusting the priorities, delivery, or requirements of existing degree specializations without making major curricular changes.
3. Adjusting degree programs: actions that would adjust degree expectations including alternatives to current degrees and degree structures.

4. Department level suggestions: mainly about support and development of faculty and teaching assistants.
5. Student support: suggested ways of ensuring appropriate expectations, improving the sense of community, supporting appropriate career preparation, etc.
6. Career development: actions to help students prepare for post-graduation opportunities.
7. Professional registration: specifics related to preparing BSc students for registration as professional geoscientists.
8. Marketing recommendations are in the Marketing main menu section.

The **21 recommendation categories are summarized** on this table which characterizes them in terms of their type, the implementation context and rough measures of urgency, impact, cost of implementation and cost of sustainment.

All specific suggestions are listed on a separate page.

4.1.2 How did these recommendations emerge? What inspired them?

Many come from faculty discussions, interviews and surveys. Some are specific recommendations articulated by at least a few different faculty members. Some arise in response to perceived opportunities, imperatives or barriers (eg specific questions in interviews). Others have been articulated by combining faculty input with wisdom from the peer reviewed literature or experiences of peers and colleagues. Students have also contributed their expectations, preferences and priorities, based on survey data and conversations with individuals.

4.1.3 How are recommendations expected to be used?

It is certainly true that curriculum belongs to the faculty. Understandably, curricula are often geared towards very specific disciplinary goals, and change is not easy, even when there is some desire to change. Some cynicism is inevitable, since curriculum reform is sometimes based on fads and box-checking rather than genuine engagement (Usher, 2018). Therefore it is anticipated that an important "next step" will be to clarify priorities among stake holders, choose the categories of recommendations that are relevant, then use the detailed suggestions as a starting point for discussions that will first clearly define the goals. Then a "project" can be initiated, practical plans and timelines can be prepared, and support can be sought as needed.

4.1.4 Assumptions underlying recommendations

If we want our programs to help **prepare students to solve global challenges** that require **interdisciplinary** work, then it behooves us to facilitate opportunities in which students practice these integrative or synthesis abilities.

Several recommendations on the degree specializations page (capstones, etc.) are driven by the need to implement opportunities for students to practice synthesis, systems & critical thinking, societal relevance, and other "*higher level thinking*" aspects of learning. One reference with an example of how this is not a new educational perspective is Yasar and Landau, 2003. EOAS faculty certainly recognize the importance of creating opportunities where students practice and re-practice "higher level thinking". There are many examples in EOAS courses that serve as useful precedent. Recommendations related to equity diversion and inclusion are also addressed under this heading.

There is precedent in EOAS. For example the ENSC program has unique characteristics such a 6-credit capstone project-based course, new "climate action labs" (in which students from all three year-levels develop community-engaged climate action skills), and 2 core courses (ENVR 200 & 300) in which students investigate major global, regional, and local environmental issues, and learn research and reporting methodologies for a range of scientific disciplines and fields.

Engineering students also take a 6-credit 4th year capstone course involving industry sponsors supporting community-based projects.

Courses such as EOSC212 and 453 and others do appear to aim to have students thinking about global research questions. The Department may want to identify further opportunities for students to focus on global challenges, interdisciplinarity, systems thinking and societal relevance. There are likely such opportunities within existing courses across the curriculum, and a departmental commitment to do make such adjustments would be needed.

NOTE: some recommendations include "boxed" sections representing further discussions. Those boxed sections are not recommendations - they are "sidebars" or "boxed" content.

4.2 RECOMMENDATIONS OUTLINE

This section lists all recommendations organized into 21 categories. **Details are provided in subsequent sections** for each of the 21 main recommendation categories. Each "link" points to corresponding details at the online blog site, while identical content is in corresponding sections of this document – sections 4.3 through 5.4.

4.2.1 Target: Enhancing Courses

1) **Rejuvenate syllabi and Course Learning Outcomes (CLOs)** (link)
   a) Why syllabi and CLOs? To … (4 items)
   b) Consider doing … (3 items)
   c) How? requires … (6 items)
   d) (Further discussion)

2) **Enhance QES learning by focusing on "quantitative critical thinking"** (link)
   a) Share content adjustments with colleagues.
   b) Focus course adjustments on fostering, practicing and assessing "process oriented thinking".
   c) Foster higher-level quantitative thinking and decision making abilities.
   d) Integrate computation into the learning of physics and math
   e) Artificial intelligence and machine learning is considered by many to be a priority moving forward.
   f) Incorporate aspects of justice, diversity, equity and inclusion (JEDI) (4 points).
   g) Engage students as co-creators of their education.
   h) Suggestions by EOAS faculty for specific new courses (5 items)
   i) Considerations regarding new courses (8 points).
   j) Regarding specific existing courses (3 mentioned).
   k) Consider some names of courses – make them less abstract?

3) **Increase use of applications and context** (link)
   a) Seek relevant contexts for learning fundamentals that are not research oriented.
   b) Begin a module or concept with the "need" rather than the abstract development of theory.
   c) Share contexts used with colleagues teaching senior courses.

4) **Quantitative concepts in service courses** (link)
   a) A new first year course is discussed elswehere
   b) A "champion" is needed who interests in this idea and is given time and space.

c) Introduce a rotating delivery model
d) Adjust content and activities to focus LESS on "*how it works*", and MORE on "*how we use what is known .... etc.*"
e) Revise and simplify the EOAS general goals for non-specialist courses.
f) Initiate a project to discuss shortcomings and opportunities related to revised goals. (Would need funding)
g) Incorporate "stories" (eg. readings) that are less descriptive and more about "ways of knowing" or "managing" for the good of communities.

4.2.2 Target: Existing Degrees

5) **Revitalize degree priorities and corresponding PLOs** (link)
   a) Aim for consistency across specializations
   b) Commit to 2 or 3 structured workshops with the goal of defining priorities and articulating them as PLOs
   c) Factors to consider: (6 items)
   d) Map course learning outcomes (CLOs) against PLOs
   e) Some examples and guidelines (7 items)
   f) Assess results.

6) **Enhance delivery of existing degree programs** (link)
   a) Implement regular curriculum review procedures.
   b) Increase transparency related to departmental priorities.
   c) Introduce contextual threads that span several courses.
   d) Focus attention on developing the maturity of "geoscientific thinking"
   e) Quantitative learning in non-QES EOAS specializations

4.2.3 Target: Adjusting Degree programs

7) **Adjusting current degree programs** (link)
   a) The Major in Earth and Ocean Sciences
   b) Add a capstone requirement (5 items about tactics or examples)
   c) Student portfolios
   d) Introduce a broadly-based, impactful foundational course (4 items)

8) **Alternative perspectives on a QES degree** (link)
   a) An over-arching QES degree?
   b) Consider an optional QES stream within the ENSC specialization involving existing EOAS courses.
   c) Could students achieve a program's goals (PLOs) in ways other than taking defined courses?
   d) Alternatives to conventional course structures.
   e) 'Badges', micro-credentials, course components;
   f) Examples of creative synergies between related groups

4.2.4 Target: Ideas at the Department Level

9) **Enhance and streamline faculty & TA support and development** (link)
   a) Enhance QES researcher interactions with undergrads:
   b) More regular and informative communication about teaching.
   c) Address the strain or challenges facing faculty
   d) Professional development for EOAS faculty; possible workshops (7 items)

e) Graduate student training (3 items)
f) Continue supporting Justice, Equity, Diversity and Inclusion initiatives

4.2.5 Target: Student Support

10) **Increase students' sense of community within EOAS & QES3** (link)
    a) Introduce (or adjust) an EOAS faculty service duty, to be called "Undergraduate Liaison".
    b) Actively and regularly engage with student clubs
    c) Instigate a club or interest group that could be called something like the "quantitative Earth sciences interest group".

11) **Improve the efficiency and efficacy of QES program advising** (link)
    a) Provide EOAS student advising resources via Canvas. In progress – see the Canvas Resource discussion page or the Canvas site itself (CWL required).
    b) Advisors should consider interactions with QES students more as "mentoring" rather than as simply providing advise about degree programs.
    c) Honors students could be better supported.
    d) Guidelines for registering as a Geoscientist in Training in Canada are not clear within EOAS (QuEST project activities are working to address this concern).
    e) Include support specifically targeting preparation for post-graduation opportunities
    f) A page of guidelines for instructors provides (and explains) key resources related to undergraduate teaching and student support.

4.2.6 Target: Career Preparation

12) **Incorporate career-related settings into learning activities and tasks** (link)
    a) Make use of UBC's Career Centre. They are eager to contribute workshops, presentations, etc.
    b) Establish a Department-wide set of objectives and corresponding strategies for incorporating career preparation explicitly and transparently into courses and curricula
    c) Adjust course syllabi, learning goals and maybe even formal course descriptions to highlight how career-relevant learning is occurring next to learning goals that emphasize fundamentals & scientific values.
    d) Actively facilitate career exploration (7 items and ideas)
    e) Consider an official "course" or "for credit" career-development experiences.
    f) Highlight the importance of QES professions in terms of impacts on society.
    g) Three suggested tactics for career development.
    h) Incorporate DEI (or EDI or JEDI) aspects w.r.t. career preparation.
    i) Aspects related to professions are in the next section.

13) **Improve the support for professional registration.** (link)
    a) Appoint a Professions Advisor, ideally one person for all and who can liaise with EGBC.
    b) Clarify student advising strategy regarding professional registration.
    c) Prepare and submit for vetting a selfcheck list for geophysicists that aligns EOAS courses with EGBC requirements. (DONE, Oct 2023)
    d) A slight adjustment to geophysics degree requirements
    e) UBC's career Services should eventually be appraised of the results of mapping UBC degree specialization course lists against EGBC requirements.
    f) Other EOAS disciplines would benefit from notes regarding preparation for formal "professional".

4.2.7 Target: Marketing QES

14) **A quantitative EOAS first year course** (link). Numerous specific suggestions, ideas and thoughts are included, organized into three sections.
    a) Regarding development of such a course
        i) Such a project needs a complete proposal
        ii) The team …
        iii) Support in terms of teaching/learning expertise, project coordination and teacher buyout
        iv) incorporate proven best-practices
        v) The goal should be to not to teach facts, figures and procedures about Earth and climate, but to gain familiarity with quantitative ways of thinking needed to understand how Earth works, and for sustainable, responsible stewardship of our planet and its resources and environments.
        vi) Consider precedent from other institutions,
        vii) Determine likely students
    b) Regarding scope of coverage and content themes
        i) Two models for developing course module content.
        ii) Build a modular course
        iii) Design content and learning activities that point at QES programs, courses, & experiences.
        iv) Content and contexts need to be inspiring.
        v) Jupyter Notebooks are attractive because …
        vi) explore the global community of geoscience educators teaching "first-exposure" courses
        vii) Several potential themes were discussed (5 points)
    c) Regarding teaching models
        i) Choosing teaching tactics is a second step
        ii) Regarding the choice of teaching model (3 points)
        iii) Single, two, or many teachers are options.
        iv) Traditional lecture, online, a truly flipped class … or a hybrid?
        v) Labs are considered awkward

15) **Showcase student learning and experiences** (link)
    a) The communications team could do with a designated "student liaison" person.
    b) Showcase types of experiences rather than specific products generated by individual students. Possibilities include (5 ideas)
    c) Existing and new web content about students needs to be re-purposed to *inspire* rather than simply to *inform*.
    d) Feedback from students could be selectively presented.
    e) Departmental public relations work could work more closely with students,
    f) EOAS social media content producers could engage more regularly with students
    g) The ways undergraduates are engaged within the EOAS Community need showcasing.
    h) An EOAS blog site may be more efficient to maintain than the EOAS website.

16) **Establish a sustainable marketing strategy.** (link)
    a) The Department would benefit from additional dedicated support for marketing
    b) Add a QES faculty member or graduate student to the EOAS communications team
    c) A marketing vision and corresponding strategies focusing on under-enrolled specializations is needed.
    d) To incorporate JEDI perspectives into a marketing strategy, refer AGI's "vision and change" document
    e) make more use of brochures, business cards, a couple of informative presentation slides, etc., prepared by the EOAS communications team.
    f) Geophysics faculty rarely teach in EOAS first year courses.

g) Further labour market research is needed identify concrete examples of diverse career opportunities for QES graduates,
h) Increase the visibility of EOAS QES degrees and research at conventions, tradeshows and meetings

17) **Attract BSc students as they choose their degree specialization.** (link)
a) Be visible in 1st year math, physics, and chemistry (piloted in winter term, 2023)
b) Be more active in Science Undergrad Society
c) Engage with more FoS activities, e.g. science-rendezvous-2023.
d) Be more visible at "Meet Your Major".
e) Explore UBC science social media
f) There are undoubtedly other avenues for engaging with incoming and existing students; this needs research, prioritizing, and action-planning.

18) **Foster partnerships emphasizing QES** (link)
a) The Communication Director and their role & team could be more visible to EOAS faculty
b) EOAS and ATSC courses should be made more accessible to physics &/or other students.
c) Connect regularly with other BC post-secondary schools.
d) Co-ordinate with Mining Matters in outreach efforts to students and public
e) The organization MineralsEd has a volunteer program called "Geoscientist in the Classroom".
f) Promote more aggressively degree minors & combined options in EOAS disciplines. (3 specific points)
g) An "Introduction to geophysics for geotech/mining students" course or module (online and/or in person) may be a way of connecting with other schools & colleges,
h) Establish more concrete connections to Canadian Earth Science community.
i) Develop opportunities to experience QES in action as a 1-hr lesson, or 1/2-day workshop, or multiday enrichment opportunity. (2 specific points)
j) PME could increase exposure to quantitative aspects of EOAS and Earth sciences generally
k) Connect with UBC's "Science 101" initiative

19) **Engage in active outreach to high schools and Vantage** (link)
a) QES faculty and students need to partner with PME to introduce QES content accessible to school workshops, teachers and casual visitors including families.
b) Re-boot the potential for partnering with UBC's GeeringUp.
c) Engage with high schools is an attractive idea, but we know from experience that it is challenging (12 points noted)
d) For school kids, focus on people, not "science". Let the science emerge from inspiring stories about who did what and how they impacted society, eco-systems, communities,, etc.
e) Opportunities at Vantage College: (6 points noted)
f) Questions re. Vantage to resolve (4 points noted)

20) **Alumni engagement** (link)
a) Can the department engage with alumni without going through UBC alumni "system"?
b) Explore creative ideas from the literature,
c) Regarding alumni profiles …
d) Industry contacts were gathered (36 to date) – followup is needed.
e) Gather public-domain alumni information based on LinkedIn data
f) Showcase pathways into geoscience occupations using an efficient model developed at Boise State University.

21) **Enhance EOAS website content for QES recruiting** (link)

a) Each web-content suggestion is not "difficult" but needs to be on an active task-list for the website and communications teams.
b) Existing and new web content about students needs to be re-purposed to inspire rather than simply to inform. (4 points)
c) Reintroduce (simplified) information about EOAS courses.
d) Make scholarships & awards from outside UBC more visible
e) Build a showcase page about courses involving physics & computing like the one for climate related courses.
f) In the EOAS website's "Degrees" section add a Combined Options section
g) Augment and modernize the QES & geoscience careers and opportunities page (9 points).
h) Improve the FoS page "What can I do with a BSc in Geophysics?".
i) The alumni "showcase" page needs modernizing and maintaining regularly.

4.3 Courses-level recommendations

These are recommendations that can be applied in a single course or a sequence of courses. Some ideas are appropriate for any course, while others refer to a specific EOAS course or course sequence. A possible new first year course is discussed elsewhere.

4.3.1 Recommendation 1: Rejuvenate syllabi and CLOs

Well-crafted **syllabi** with **Course Learning Objectives** (CLOs) are critical for (a) improving consistency and coherence within a sequence of courses, (b) helping students set appropriate expectations and self-asses their progress, and (c) helping instructors ensure the education they deliver remains focused on the needs of students and the discipline. They can evolve over time, but they do need to be written carefully to be optimally effective. Consistency among EOAS courses will benefit students by making it easier to compare courses and set expectations for their pathway through degree requirements.

EOAS is in fact relatively compliant (see the QuEST report on syllabi and CLOs) – but not 100%, nor are they particularly consistent across courses.

1. **Why syllabi and CLOs**? To ...
    - publicly characterize our curriculum and each course more fully,
    - share among colleagues so they can see intentions and outcomes for related course sequences, recognize pedagogies and student products & experiences.
    - help students choose the courses they want and need,
    - ensure students set appropriate expectations about content and learning experiences.
2. **To consider doing**:
    - All EOAS courses need current and complete syllabi that are compliant with UBC's standards.
    - Syllabi *should* be made publicly visible.
    - Faculty would ideally be reminded at end of each term (December and May) to revisit and revise – especially thinking carefully about whether CLOs are effectively articulating the expectations. Regular "maintenance" need not be onerous.
3. **How**? Requires
    - Departmental commitment & explicit expectations;
    - A place to keep and edit them, perhaps a standard syllabus webpage for each course with a template for maintenance;
    - Regular reminders, ideally at end of each term (December and April);
    - Use the UBC syllabus template which includes guidelines for syllabi and CLOs;
    - Engage the help of a science education specialist to assist, review and refine.

- Evidence-based advice for what makes an effective learning goal can be found on the Carl Wieman Science Education Initiative's Learning Goals page.

BOX 1 - Further Discussion of syllabi and CLOs

The QuEST report prepared based on 27 syllabi includes discussions of (a) why syllabi are necessary and should be public, (b) what they should include (based on UBC's requirements), and (c) where to find guidelines for making an effective syllabus. See UBC's calendar page and and Senate Policy entitled "Content and Distribution of Course Syllabi" (there is a template here).

Regarding CLOs, instructors would articulate the corresponding capabilities based on assessments they use that "prove" students have succeeded. For the same reasons as syllabi, carefully constructed and well maintained CLOs are critical for ensuring consistent, predictable, relevant and effective learning experiences across the curriculum. Updating the CLOs can be considered part of maintaining a complete syllabus.

4.3.2 Recommendation 2. Enhance QES learning by focusing on "quantitative critical thinking"

Aspects to considering include changes to content or activities in individual courses in order to emphasize "critical quantitative thinking" and ensuring that students use, reuse and apply new capabilities throughout their curriculum. Specific pedagogies are not the focus here, but see also the section "Regarding pedagogy" on the methods and frameworks page.

Recommendations for adjusting degree *programs* are on the degree specializations page. EDI aspects are also discussed there. See also related recommendations at the degree or Departmental level. Here the focus is on what can be done in an individual course.

1. **Share content adjustments with colleagues.** Changing course content and learning activities is up to instructors, but **consistency, continuity** and strategic **repetition** of earlier content in senior courses depends on discussion within faculty groups.
   - This means content revision should be driven by:
     - *revisiting* or *reusing* prior learning contexts,
     - *applying* prior learning,
     - *practicing* new skills more than once,
     - making *judgments* or *creating* with prior knowledge & skills.
   - **Why?** The goal is to support building and retaining new knowledge, skills, & especially "attitudes" such as the habits-of-mind associated with mature, critical, quantitative and data-oriented thinking. **For example**, EOAS has already committed to one preferred, open-source based computing environment (Python), so that students can build upon computing skills as they progress through their degree programs.
   - **Evaluating** how well changes have improved student capabilities (i.e. "learning") is a key driver of what and how we teach.
2. Focus course adjustments on fostering, practicing and assessing "**process oriented thinking**".
   - It is relatively easy to check a student's "answer" but it is more difficult to assess the student's "process", i.e how they got the answer.
   - Therefore instructors are advised to seek **expert advice & support** to develop more effective ways of (a) causing students to practice new skills effectively, and (b) assess those skills rather than the outcome or product of applying those skills. Departmental, Faculty of Science and UBC expertise can help instructors gain teaching and assessment expertise.

3. **Foster higher-level quantitative thinking and decision making** abilities. Recent and current research about teaching math and physics should be explored and discussed by QES faculty to determine preferred improvement options. Examples of precedent are given in the "*Further Discussion about critical quantitative thinking*" expanding section below.
4. **Integrating computation** into the learning of physics and math is essential moving forward. Future professionals and academics are already increasingly dependent upon computing capabilities when addressing problems and questions that involve mathematics and physics. This has been an issue in undergrad physics curriculum for some time – see for example Chonacky and Winch, 2008 in the American Journal of Physics.
5. **Artificial intelligence and machine learning** is considered by many to be a priority moving forward. EOAS does have one undergraduate course in which AI/ML ways of thinking are introduced but it is taken by very few undergraduates. Introducing these ways of thinking in smaller "doses" in courses taken more widely would benefit students' longer term abilities to consider whether AI/ML methods may be appropriate for tackling a wide range of problems.
6. **Incorporate aspects of justice, diversity, equity and inclusion (JEDI).**
    - See for example to Shafer et. al. July 2023 as a starting point. Also, the AGI's "vision and change" document (Mosher and Keen, 2021) has sections and discussions of recruiting for a "diverse and inclusive community". "Diversity" and "diverse" are mentioned 50 and 47 times respectively. This may be more effectively addressed at "courses" level. It includes diversity of application, and awareness of potential "colonial" perspectives about data, resources and land-use decisions.
    - Articulate the notion of bridging quantitative thinking with the rights, concerns and perspectives of different cultural groups both locally and globally. Laura and Shandin are likely the first point of contact for these deliberations. Refer to Laura's interview.
    - Emphasizing societal relevance of learning also increases visibility of JEDI issues.
    - The page with recommendations related to career preparation offers suggestions for helping ALL students (regardless of their prior experiences, family support, etc.) identify and pursue opportunities to gain relevant non-academic experiences, and succeed at that critical post-graduation step of finding the right job or graduate school.
7. **UBC's Strategic plan** states that best efforts to transform education include "*...engaging students as co-creators of their education*".
    - Corresponding adjustments can be made to any course by allowing students to make some choices about what they learn.
    - For example, some projects, labs or assignments could incorporate some degree of choice regarding the problem that a student solves or the task they pursue.
8. **Suggestions by EOAS faculty for new courses:** ideally these should be proposed in context of specific *curricular goals*. Search for opportunities that are equally important for geophysics, atmospheric science and oceanography students. Examples already exist, eg. EOSC 410. Suggested examples from discussions in 2019 and 2020 include:
    - P. Austin: A course that uses a text like Denis Hartmann's Global Physical Climatology (free if you're on our vpn). Predicts ~15 students / yr in such a course. Example 3rd yr course taught at Washington (https://atmos.uw.edu/~dennis/321/) or grad course https://atmos.washington.edu/~dennis/571/.
    - P. Austin: Consider broadening topics in ATSC 409/EOSC 511 (numerical methods) and offer it every year. That way, 3rd yr students experience simulation/model building as soon as they've completed ODEs.
    - E. Haber's image analysis course.
    - L. Heagy's rejuvenated applied geophysics EOSC 454, likely to be co-taught with a graduate version, hopefully starting in Jan. 2024.
    - Climate physics – P. Austin and R. White (this may be in progress as of 2022).

9. **Considerations regarding new courses;** asking the following questions will help ensure the course is well-placed within the department's various curricula:
    - Is the course being proposed because the capabilities to be taught are becoming important for future occupations students will pursue? How is that known?
    - Is the course being proposed because the subject is a topic of current research?
    - Will the course be "small" and aimed at more mature students? Or is it a foundational course that provides skills and knowledge students need in their 3rd or 4th year? If the course is not a senior course, then be careful of developing a "dead end" course, i.e. one in which students learn capabilities that will not be practiced in subsequent courses.
    - Can a graduate version of the course be taught simulataneously?
    - Can the suggested course be made to become a useful contribution to the curriculum of all QES programs?
    - Is it aiming to be an elective accessible to "any" student?
    - If there are pre-requisite expectations (eg. differential equations), how much experience will be required and how will incoming students' abilities be assessed? Will resources be provided to help fill gaps?
    - One current example is the proposed new EOSC 2xx course on geophysical image processing. How this process unfolds beyond 2023 could become a model for how best to tackle considerations introducing new courses into the EOAS suite of offerings.
10. Regarding specific existing courses:
    - **EOSC 213** and **EOSC 329:** EOSC 213 is apparently not prerequisite for any other GeolEng courses. Consider adding some programming and/or Jupyter notebook use into EOSC 329. This should reinforce prior learning while elevating the content and learning tasks to modern, computing-oriented methods of addressing the quantitative nature of groundwater studies.
    - **DSCI 100:** the OCESE project helped prepare a python-based section, now being taught by L. Heagey, but incorporating **Earth science oriented data sets** has not yet been accomplished.
    - **EOSC 212** is a successful course which was developed a decade ago based on research about "scientific expertise", and summarized in Jones, Jellinek,& Bostock, 2012. Current learning goals target **scientific thinking** through • Reading and using science articles, • Communicating, • Awareness of your science learning, • Qualitative and basic quantitative data analysis, • Healthy scientific skepticism, and **for specific topics:** • relevant concepts & topics (varies), • Models versus data, • Working with scientific information. To leverage the success of this course, it may be timely to consider options such as
        - "Polishing" the course so it can be taught on a rotating basis by any faculty member;
        - Incorporating guest appearances from EOAS researchers (faculty, PDFs/RAs, graduate students);
        - Increasing the emphasis on "critical quantitative thinking";
        - Adding modules that are involve "industry" or "societal" contexts to complement the current focus on thinking associated with "scientific research".
    - **EOSC 410:** It used to be that either one of EOSC 212 or ENVR 300 was required as a prerequisite. Recently this constraint seems to have been removed, however some older prerequisite listings still include these requirements.
11. **Consider names of courses** (existing or new): Could they make clearer why the course will be important students rather than simply stating the abstract subject? Hydrology courses have obvious relevance to student while "applied geophysics" or "fields and fluxes" etc. may seem relatively obscure.

BOX 2 - Further Discussion about critical quantitative thinking

"C*ritical quantitative thinking*" may be the most important capability to promote more explicitly. This aspect of quantitative learning is distinct from learning about specific mathematical techniques, data-science methods, and so on. It means spending time having students make decisions and judgements with physics, data sets, and mathematical models, even if that is at the expense of covering fewer distinct quantitative concepts. During interviews, faculty were eager to distinguish between learning new concepts and techniques versus developing maturity regarding use of mathematical or data-science components of work. However, tactics that will support corresponding student learning are not necessarily obvious, especially since most students are not future graduate researchers. It will be worth seeking support from science or education experts who can research precedent and help with instructional design.

Current (2023) groups who are actively researching "critical thinking" for physics education include the Cornell Discipline-based Education Research - Physics group (primarily Prof. N. Holmes). At Stanford, the Weiman Group studies the thinking of skilled practitioners in science, engineering, and medicine, and is developing methods for measuring and teaching this expert thinking. Creative learning activities can be developed that are both more effective at helping students learn at "higher levels", and more inspiring (resulting in increased motivation). Earlier work in EOAS includes Jones et al 2012 who demonstrated several examples of tactics developed for a second year course based on knowledge about what constitutes "scientific expertise".

A few examples of ways to foster quantitative critical thinking include:

1. There are emerging **research-based strategies** for helping students develop more mature critical quantitative thinking abilities such as decision making (Holmes et al., 2020) and problem solving (Burkholder et al., 2020) when confronted with physics, mathematical or data science tasks. The tactics found by both groups essentially involving structuring assignments to emulate the thinking sequences and decision points of expert scientists and engineers. Students are required to make choices at specific decision points rather than being told the next step or decision. Designing learning activities like this is not trivial and takes practice. However a suite of exercises in a course can be adjusted in small steps without re-inventing the course. Referencing relevant literature is helpful, seeking input from science education experts is recommended, and creating effective exercises that both assign and assess quantitative decision-making will result in more skilful and confident students at any level from beginners to 4th year level.
2. In the context of **chemistry**, Hansen et al (2016) discuss tactics for engaging students with original research as they develop analysis and software skills. Students engage with data related to research of current graduate students by performing analytical tasks guided by commentary from the researcher. This provides opportunities for undergraduates to collaboratively practice problem solving and trouble-shooting, and connect with graduate students. This benefits both undergrads and grads.
3. In a more purely **mathematical context**, Khotimah and Masduki, 2016, discuss improving problem solving with differential equations by designing problems with meaningful and inspiring contexts that involve some aspects of discovery.
4. Lewis and Estis, 2020 explore use of **team-based inquiry learning** to enhance mathematics content mastery and flexible problem solving skills.
5. An approach for building a **mathematical modeling** course for undergraduate mathematics majors and minors is described by Rohde Poole, 2022. Their goal was to develop students' mathematical thought processes, abilities to analyze and evaluate mathematical models, and

teamworking skills, all in an upper division undergraduate course that has differential equations as a prerequisite.

4.3.3 Recommendation 3. Increase use of applications and context

Suggested tactics for amplifying the relevance in individual courses

In addition to its influence on curriculum, the context or relevance of quantitative Earth sciences is also identified as a priority in "marketing" efforts. Inspiring contexts that could be used in courses can be informed by efforts to showcase the impacts of geoscience on society that are being prepared for public outreach and student recruitment.

1. Seek relevant **contexts for learning fundamentals that are not research oriented.** Make use of case histories, alumni experiences, the "applied" literature, and public or press-related materials. Choices would ideally resonate with instructors' interests, but the priority is inspiring students, most of whom will be employees, not scientists.
2. **Begin a module or concept with the "need" rather than the abstract development of theory**. This is because when students can relate to the context – either personally or as relevant to society – they are more motivated and learning is much improved. An effective cycle of learning involves:
    - establishing a setting to 'hook' the learner,
    - identifying the need for the learning that is about to begin,
    - using that setting during development of the concept and for assignments,
    - then closing the segment with something like "how as what we've learned made a difference to the original problem?" This last step can be done by discussion or as part of an assignment – its purpose is "reflective" and causes the learner to re-connect the new (possibly complicated) concepts with a reason for knowing it.
3. **Share contexts used with colleagues teaching senior courses** so they can re-visit settings students encounter in early courses.
    - Seeing more advanced treatments of problems first considered at elementary levels increases motivation and retention.
    - Learning efficiency is also improved because students will spend less time "coming to grips" with the context for their assignments.
4. Increased use of projects, capstone experiences, guests or visitors, and other tactics are discussed in the section about "career preparation".

BOX 3 - Why focus on context?

The importance of context is certainly recognized by EOAS faculty as a means of bridging learning about fundamentals and developing work-related skills.

- Based on interviews with faculty about career preparation, the two most commonly used tactics reported by instructors were "working with teams and/or peers" and "using real contexts for problems and projects".
- Participants in paired interviews with EOAS faculty also identified context-oriented teaching as a key strategy that could be used more widely.
- When instructors were asked in the learning tasks survey "*In your course or across the Department - and assuming that implementation was practical - which five (5) of these tactics do you think would be MOST effective at helping EOAS undergraduate students develop into professionals?*" their top response was "Increased use of real contexts for problems & projects". See results of this question on page 6 of the learning tasks results document.

Students also want contextualized learning. Recent geophysics students have stated that they aspire to pursue professional geophysics careers. This is evident from conversations with current students (2021) and results of a survey targeting geophysics students, summarized in Jolley, 2018. One student commented: "*The program leans heavily to the global geophysics side of the field and does not prepare students for industry. It needs to be updated to remove old course requirements (Phys 203) and fulfill EGBC requirements*".

Others asked for clarity regarding requirements for professional registration. Applied geophysics (or atmospheric science or oceanography) may not be the focus of some EOAS faculty, but "techniques" for doing "useful things" are more inspiring to beginners than theory or abstract research questions. EOSC350 may be "easy" for geophysics students but should be required as an exposure to the breadth of methods used for subsurface investigations. Rejuvenating EOSC 454 is also important, but represents an opportunity for increased "depth" of learning (as opposed to "breadth") at a level appropriate for geophysics students.

4.3.4 Recommendation 4.Quantitative concepts in service courses

From two points of view – teaching for an "educated citizenry" and attracting students into EOAS degrees – EOAS service courses could do better at reflecting the quantitative nature Earth science knowledge. When a course focuses on "show-and-tell" or mainly descriptive content, it perpetuates the misconception that Earth sciences are mainly descriptive, not rigorous, and somehow less important compared to the standard four sciences (physics, chemistry, biology, mathematics). Timing may be right given the evolving expectations regarding science courses by non-science degree programs (eg Arts?).

Some suggestions for how to implement this recommendation include the following. Note that recommending specific teaching tactics is beyond the scope here, but see the Pedagogy section of our Methods and Frameworks page for some suggestions.

1. **A new first year course** about quantitative Earth sciences for capable students is discussed separately.
2. **A "champion" is needed** who (a) has interests in this idea and (b) is given time and space to promote and initiate corresponding changes. Recent adjustments to EOSC 112 represent a successful precedent, but similar enhancements should be considered across all EOSC 1xx and 31x courses.
3. Consider introducing a **rotating delivery model** in which all (or most) EOAS instructors contribute to the teaching of service courses every N years. Other institutions (and UBC departments) do this, and faculty who say this is rewarding claim that it keeps them attuned to students, their priorities and those of wider society.
    - No faculty member should truthfully be able to claim to be unable to teach any EOAS subject at the first year introductory level.
    - Avoid the "serial monogamy" model of teaching in which more than 3 or 4 instructors teach 2-3 weeks only before handing off to another instructor (Jones and Harris, 2012). Students may like this for various reasons, but it is not conducive to a cohesive, predictable learning experience.
    - The benefits of exposure to several EOAS faculty can be gained by introducing regular guest contributions, rather than "teaching" for just a few lessons.
4. **Adjust content and activities** to focus LESS on "*how it works*", and MORE on "*how we use what is known to make decisions affecting individuals, communities, industries and stewardship of our planet, or to understand better how our unique planet and it's life & ecosystems work.*".
5. Revise and simplify the EOAS **general goals for non-specialist courses.** They date back to roughly 2010 and are not really "in use". **Specific learning goals** are needed that target:
    - the quantitative nature of Earth sciences;

- "ways of knowing" and implications for decision making;
  - notions of sustainability;
  - foundational Earth science concepts such as "observational science", deep time, the coupling between life, evolution and how Earth works;
  - employing Earth science evidence for decision making that affects communities and long term sustainability; etc.
  - Including **attitudinal learning goals** that exemplify the styles of evidence-oriented thinking and maturity regarding uncertainty and incomplete data that reflect the way individuals and society must think if sensible decision making is to occur.

6. Initiate a project in which **shortcomings and opportunities** related to revised goals are discussed for each service course, perhaps using a SWOT approach. No need for "new" courses – the existing suit of 1xx and 31x courses are fine.
   - **Seek funding** such as a "small TLEF", involving a project lead and short, focused engagements with EOAS faculty. **A project goal could be**: "*to revise service course learning outcomes to better reflect the ways that society depends upon evidence-based Earth science information, and to generate a road map for evolving existing courses so they can deliver those outcomes*".
7. Incorporate "**stories**" (eg. readings) that are less descriptive and more about "*ways of knowing*" or "*managing*" for the good of communities.
   - Injecting content to address attitudinal goals may mean less "content" – but that's OK. A climate emergency – yes – but in fact we are responsible for a whole planet, involving agriculture, population, resources, biodiversity, climate – etc.)
   - Stories should ideally be relevant to students in all degree specializations (eg, see EOAS1xx demographics from 2019, and revisit for current data).

BOX 4 - Further Discussion about quantitative content for service courses

How much - and what types of - quantitative content could our service courses include? McFaddden et al., 2021 provides data on use of quantitative and data-related skills in introductory and majors geoscience courses in US institutions. That research provides a base line for what was being taught some years ago, but it could be argued that UBC students should be more capable than the average across all institutions.

Learning about the quantitative nature of Earth sciences does not mean students must "use mathematics", or "arithmetic". The point to convey is that characterizing how Earth works, and applying that knowledge to make important decisions affecting individuals and communities, depends upon quantitative ways of thinking. Data, data analysis, statistical ways of thinking, modelling (which is inherently quantitative), etc. - these are quantitative ways of thinking that make it possible for humanity to act as responsible stewards of our Planet. Neglecting these forms of thinking and decision making results in mistakes and failures.

Incorporating quantitative components into courses taken by non-mathematically inclined students is certainly feasible - with care, creativity and attention to precedent. This could become a focus for an educational leadership faculty member interested in shifting our service courses towards more quantitative styles of thinking, without making them appear "math intensive". Examples of precedent include:

- Abramovich and Grinshpan, 2008, "*Teaching Mathematics to Non-Mathematics Majors Through Applications*" which focuses on the role of applications in learning mathematical concepts.
- Instructional computing tools and activities (eg "dashboards" developed as part of the OCESE project) are gaining popularity among instructors and students. The goal is to stimulate students'

curiosity & motivation by engaging them with data and quantitative information conceptually, without getting side-tracked by the rigour of the mathematics itself.

- For further inspiration, see the so-called EDDIE modules.
- Other activities and resources can also be found at SERC by search that repository "quantitative" then refine using lists on the right side of the page.
- Locally in EOAS, ATSC 113 and EOSC 112 are examples of progress in the last few years.

4.4 ENHANCE EXISTING DEGREES

These suggested actions are about adjusting the priorities, delivery, or requirements of existing degree specializations without making major curricular changes.

4.4.1 Recommendation 5. Revitalize degree priorities and corresponding PLOs

Well-crafted **Program Learning Objectives** (PLOs) are a precursor to curriculum mapping which in tern is useful for both review and renewal. UBC's CTLT is eager to provide support for crafting or clarifying PLOs.

BOX 5 - Why focus on PLOs?

The "*... development of Program Learning Outcomes (PLOs) across campus and ... ensuring that mapping of outcomes to the curriculum takes place ...*" was a stated recommendation in the "2018/19 Quality Assurance Process Audit The University Of British Columbia " (pg 10). The results for EOAS degree specializations are given on the corresponding Program Calendar Pages: see them under the "Learning Goals" heading on their respective UBC Calendar pages: Atmospheric Sciences; Earth and Ocean Sciences; Environmental Sciences; Geological Sciences; Geophysics; Oceanography. **These objectives are compared here.**

Although current, these program objectives are 3-4 years old. Reviewing and renewing these will ensure they reflect the aims and aspirations of degree specialization programs and thus increase transparency, helping students and instructors set appropriate expectations about what will be learned, which skills will be developed and how success will be measured. The discussions necessary to achieve consensus will also help faculty recognize how students are expected to progress from year to year, and inspire opportunities to be more explicit about how the learning at senior levels depends upon abilities developed in earlier courses.

To ensure review of PLOs is carried out in an informed and efficient manner, precedent and perhaps an existing framework should be used. There are many frameworks for developing or reviewing PLOs, but one example is the Degree Qualifications Profile (**Gaston, Schneider, and Ewell, 2022**). This broadly-based and widely used framework organizes degree qualifications for BSc, MSc and PHD levels into five categories: >>Specialized/Industry Knowledge, >>Broad and Integrative Knowledge, >>Intellectual Skills includes, >>Applied and Collaborative Learning, and >>Civic/Democratic and Global Learning.

Existing precedent does not necessarily have to be used rigorously, but it may help ensure a "structured" consideration of curriculum. More locally, CTLT will be eager to help formulate and optimize PLOs; see their PLO page. Details in the following drop-down provide inspiration for defining objectives that are forward looking.

BOX 6 - Goals for 21st century Science Education

In his article "*Science education in the 21st century*", Sun Kwok, 2018 articulates and discusses several commonly debated aspects of science education & curricular reform. His section "R*ationale and objectives for science education reform*" reads like a list of higher level degree program learning objectives. If the goal is to train students as people of intellect, not for a vocation, then program objectives could include:

- *Master methods such as building models, constructing experiments, taking data, making observations, revising models based on data and observations, and communicating results.*
- *Acquire abilities to solve problems by studying examples of previous work.*
- *Develop free, bold, independent, and creative thinking.*
- *Make rational judgments that raise decision-making above the ignorance and prejudice that are prevalent in society.*
- *Develop a sense of curiosity and acquire the confidence to ask questions and challenge assumptions.*
- *Acquire knowledge about our world and awareness of how nature works.*
- *Think analytically and quantitatively, keeping an open mind, and remaining independent of public opinion.*
- *Build versatility of mind enabling abilities to take on any job.*
- *Lay the groundwork for lifelong learning, as society's needs are constantly and rapidly changing.*

Of course, discipline-appropriate capabilities would be added to these "generic" aspirations, but these represent a good starting point for deliberations about defining the Department's QES (and other) degree options.

Existing PLOs for EOAS degree specializations are fairly good, but are rarely explicitly targeted or referenced in course syllabi. Specific recommendations related to revisiting priorities and PLOs follow.

1. Aim for **consistency across specializations** without substantially changing curriculum. (See current PLOs for EOAS specializations here.) Then craft new Program Learning Objectives (PLOs) for each specialization that are as compatible cross specializations as practical.
2. For each degree specialization, do this by **committing to 2 or 3 structured workshops** with the goal of defining priorities and articulating them as PLOs. Educational experts at CTLT can facilitate these actions.
3. **Factors to consider:**
    - **Consider both professional and scientific priorities** in terms of principal knowledge, attitudes, skills and habits (KASH) targeted by the core course sequences and electives.
    - **Bear in mind "desirable skills"** detailed elsewhere and anticipated demand for quantitatively skills graduates (the demand for geoscientists page).
    - **Consider establishing *principles* underlying science** – and especially quantitative – curriculum in EOAS, as was done by Kwok, 2018. The current EOAS service course learning objectives may serve as a starting point.
    - **Some PLOs may be "either-or".** For example, a BSc in geophysics might have some PLOs targeting students pursuing exploration geophysics careers, and others for students with more scientifically oriented interests (e.g. planetary geophysics, glaciology, etc.)
    - **Visibility**: PLOs should be public on the main EOAS "degrees" pages, and Course Learning Objectives (CLOs) should point to the PLOs of relevant degree programs. This can be expedited by maintaining a matrix of PLOs and CLOs.
    - **Refer to** details about current EOAS curriculum prepared by the QuEST project, including the interactive curriculum maps of quantitative courses with comments and observations.

4. **Map course learning outcomes (CLOs) against PLOs** using UBC's curriculum mapping tool. This is a straight-forward and maintainable approach to articulating curriculum for all stake-holders. Start by using existing PLOs.
5. **Some examples and guidelines:**
    - at CTLT
    - the UBC-OK Curriculum MAP online tool
    - Department of Computer Sciences' PLOs.
    - BC Sauder School of Buisness "skills map". Not a curriculum matrix but an example of defining career-related skills.
    - Matrix Approaches to Program and Curriculum Design at SERC with examples.
    - UBC's CTLT also describes curriculum mapping and can facilitate the process.
    - Curriculum map and/or program descriptions should indicate how/when/where students develop key concepts & skills (via PLOs) in each term. Curriculum should be able to demonstrate where students "Learn it -> apply it -> practice it". This could be illustrated efficiently in a curriculum matrix, annual PLOs, or other.
6. **Assess results;** some indications of effective PLOs include: they are publically visible; they identify how students will graduate as desirable employees; students can see how their course work relates to them (ideally via to measurable CLO:s); they are agreed upon widely within the department. CTLT will provide expert assistance for evaluating effectiveness of PLOs. (Kwok 2018 mentions some challenges of assessing curricular renewal using student evaluations.)

4.4.2 Recommendation 6. Enhance delivery of existing degree programs

These recommendations focus on ideas applicable to any degree program. Corresponding suggested actions targeting individual courses are in a separate recommendation.

Some ideas are presented in terms of the geophysics degree specialization, but discussions can be equally relevant for atmospheric sciences and physical oceanography specializations.

1. **Implement regular curriculum review procedures**. For example, allocate 2 hours every 2-3 years to share (a) ways courses are meeting PLOs, (b) learning strategies that are particularly successful or satisfying, (c) update on initiatives completed or in progress, (d) identify challenges, and (e) decide whether to meet again to address specific issues.
2. **Increase transparency** related to departmental priorities. In other words, make *Nurturing critical quantitative thinking with models, mathematics and data-oriented information* a Departmental priority and visibly demonstrate this committeemen. Students benefit from seeing such outcomes as a department-wide priority. Options for achieving this include the following:
    - Articulate or "map" explicitly how senior courses build upon capabilities developed in earlier courses.
    - Include carefully crafted PLOs targeting these capabilities.
    - Showcase real-world (including research) contexts where these capabilities have been instrumental in successful decisions affecting society. See also marketing recommendations.
    - **(Transparency** is a useful pervasive framework for curricular review, renewal and delivery, and is one of 6 goals in UBC's process for "program renewal". See also Winkelmes, M., 2023, "*Introduction to Transparency in Learning and Teaching.*"**)**
3. Introduce **contextual threads that span several courses**. The importance of contexts for learning fundamental concepts is discussed under recommendations for improving individual QES courses. This is a reminder of the benefits of working with colleagues to identify contexts that can be reused in senior courses after students first encounter them in early courses. This is a "low-cost" suggestion if such contexts can be found. It requires faculty communicate more regularly about their courses and how they are taught. The suggestion for regular curriculum review above would facilitate the identification of contextual threads.

4. **Geophysics for undergraduates**: Current 4th year courses appear to emphasize planetary physics. Three 4xx courses: Introduction to Global Geophysics (EOSC 444 proposed), Interior Structure of Earth and Planets (EOSC 450 - used to be "potential methods"), and Advanced Physics of the Earth and other Planets (EOSC 453) do not obviously serve the needs of students who aim to enter the workforce upon graduation. This may even cause the geophysics program to appear (to students) as an alternative to "astronomy". It also leaves students without opportunities to learn about "practical" or applied geophysics at a level of rigor suitable to a quantitative degree. This recommendation basically boils down to suggesting that QES faculty should consider course offerings in terms of students' needs rather than faculty's research preferences.

5. Focus attention on developing the **maturity of "geoscientific thinking"**. This does not necessarily mean making new courses, but rather working towards a more integrated suite of courses in which the geoscience and the physics or math pervade the curriculum more coherently rather than offering "silo'd" courses that have students working on content in isolation from other courses they have taken, are taking, or will take. For example, several key contexts could be identified that would serve as threads throughout the 3 years, culminating in a fourth year capstone requirement that draws upon skills and knowledge developed in 2nd and 3rd year courses.
6. **Quantitative learning in non-QES EOAS specializations** is somewhat out of scope for the QuEST project, however researchers in geology, environmental sciences, and biological oceanography have argued that quantitative capabilities are increasingly important and currently deserve improvment.
    - A focused discussion among relevant faculty is needed, to establish the scope and expectations for quantitative learning in these specializations. Precedent does exist for incorporating statistics, data science, modeling (including differential equations), machine learning and computer programming into geoscience courses (Jacobs, 2016).
    - A science education specialist should participate in order to research precedent and generate recommendations.

4.5 ADJUSTING DEGREE PROGRAMS

The focus here is on more involved **changes to degrees** that would likely require greater commitment and more broadly based approval.

Note that restructuring degree programs requires commitment and can be "bureaucratic". So-called "significant curriculum renewal projects" require Senate approval, and their curriculum guidelines should be followed closely. However, with care and careful design, adjustments can be designed so for "low cost" implementation, so long as a leader is chosen who can coordinate stake-holders and carry out the logistics of the project.

4.5.1 What are peer institutions doing to rejuvenate their QES programs?

The following notes are not strictly recommendations for EOAS but Stanford in particular has made adjustments that seem compatible with EOAS perspectives.

BOX 7 - initiatives at Peer Institutions

Derived from details in file CScontacts-summary.pdf. To summarize ...

- ***At UofA***, changes were made to make it easier for 4th yr physics students to jump into geophysics, and **physics now more flexible** to allow a 'minor' to be attached to the degree. Also, Python is now the standard for computational learning.
- ***At UoT***, geophysics is part of the physics department. Oceanography & atmospheric science courses are available as **electives for physics students**.

- ***At MUN***, Geoph stream students often get minor in math by adding 2-3 more courses.
- ***At CSM***, good relationships between geoph and comp. sci.
    - Geophysics profs teach a compsci courses in alternate years.
    - Cross-departmental collaborations are being pursued.
    - Excelling **flowcharts** detailing newly (2021) upgraded geophysics pages. See their geophysics page with faculty, major, minor, courses, and their program flowchart.
    - "*You don't see the gaps until you grind the crank a few times*". Therefore, **assessing impacts** of change 3-5 yrs later is critical – eg. a special retreat.
    - Working to ensure learning **goals are aligned** across the curriculum.
    - Noted that geophysics faculty do not teach in any 1st year courses which means **1st year students do not "see" geophysics**.
    - they want to ease the challenges of switching into geophysics in 3rd or 4th year.
    - Working to increase alumni engagement, including bringing in alumni who have non-traditional careers - eg in digital media, data science, etc.
    - They have "nested mentoring" a bit like Stanford - faculty plus senior undergrad and graduate student mentoring.
- **At Georgia Tech:** a somewhat "engineering" focus.
    - "**Rebound**" in enrolments is attributed to >>**introductory class** with new special section for EAS students, >>improving **advising and professional development**, and >>building a greater sense of **community**"
    - Popular **service courses** on climate and energy.
    - Upper level "Sea level and coastal engineering" course attracts ~25 engineering students.
    - **Renaming their QES major** "Computational EAS"
    - Intro to quantitative methods (2nd yr) includes **Python** and some **statistics**.
    - Earth System Modeling course has differential equations prerequisite. Upcoming changes are to be **more "practical"**.
    - **Quote:** "*Future grad students will take more advanced numerical methods later anyway.*"
- ***Stanford's*** renewed geophysics program is described next.

Stanford University

Stanford has set an excellent precedent for curricular reform of their geophysics major. Details were contributed by D.Schroeder in response to emailed questions posed by C. Schoof. Although geophysics was their context, the strategies are not discipline specific; any QES degree specialization - existing or newly conceived - could benefit from following this model, or parts of it. Details are on a one page summary of this "Stanford model", but the key components are:

1. Two explicit pipelines for students are defined: environmentally oriented and physics/engineering oriented. (EOAS could do something similar with more pipelines to accomodate all QES disciplines, and either career-oriented or scientific preferences.)
2. Core courses are reduced to the following bare minimum: (The ENSC program at EOAS also is structured around a bare minimum of core courses.)
    - Measurements, Instruments, Fields and Waves
    - Mathematics, Computation, Mechanics and Dynamics
    - Laboratory Studies
    - Exposure to the breadth of the department via an introductory course involving a "parade" of guests by all faculty plus a recitation using short readings & one problem.
    - A thesis-writing senior capstone
3. A focus on "teaching well" is paramount, including "polishing" core courses so they can each be taught by any (or almost any) faculty member without requiring re-invention.

4. Each student has several mentors: a faculty member, a grad student, a capstone project supervisor, and a new (paid) undergrad peer advisor each year. (The job of faculty mentor needn't be onerous - just timely and focused.)
5. Social events are important for building community among faculty and students.
6. Active recruiting and marketing efforts are undertaken by faculty members (some of which EOAS is already doing).

EOAS could take a similar approach by agreeing upon core capabilities described by how students would use what they've learned in each core requirement. The core could be as few as 3-5 courses. An overarching desirable capability would be that students can apply these fundamentals in a QES setting of their choice (geophysics, atmospheric sciences, etc., and applied or "scientific").

Stanford's initiatives seem highly consistent with aspirations of QES faculty in EOAS. Certainly Stanford is a different "academic environment", but their ideas are more compatible with EOAS than other schools. EOAS would need to allocate time/energy, designate a lead or "champion", and undertake honest ("brutal") evaluation of essential courses, experiences and aspirations bearing in mind the impact on students' opportunities upon graduation (including professional accreditation). This is probably possible if such a program is designed with sufficient flexibility AND significant support available to advise students early in their decision-making path.

4.5.2 Recommendation 7. Adjusting current degree programs

These suggestions involve more that tweaking the priorities or coverage of individual courses. New requirements could be met by changing an existing course to address the requirement, by adding & removing courses while maintaining existing total required credits, or by introducing a requirement that could be met with one of several option. An existing example is field experience required for registration as a professional geoscientist in BC. This can be met by taking a field course or by gaining experience – with instruction – in field operations during a work experience.

1. The Major in Earth and Ocean Sciences

The major in EOS degree has been criticized as too indistinct, however enrolments are strong, at roughly 70 students in 2020 (data). Given its popularity, there may be good arguments for incorporating more quantitative perspectives or expectations. This would need a discussion lead by faculty who are (or have been) advisors to the program.

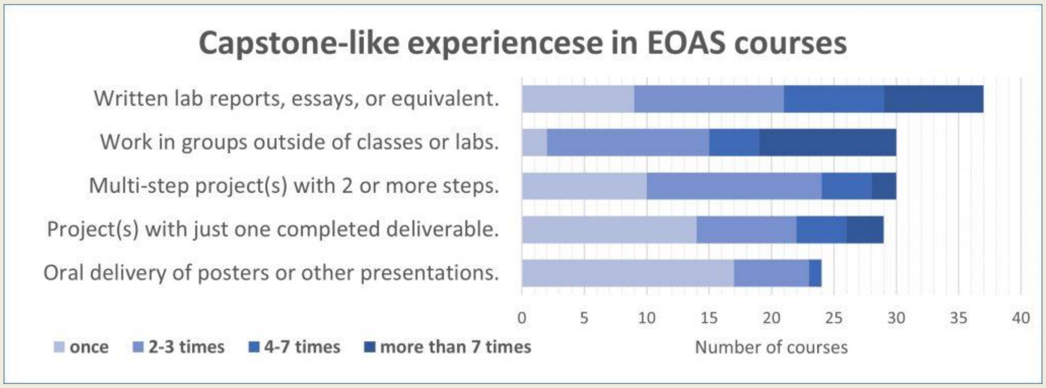
2. Add a capstone requirement

This is not a "new idea" and is used in some EOAS programs. It is well established (see C. Hunter's report for QuEST on capstone projects) as effective for inspiring students, encouraging synthesis of knowledge and skills, team work, creativity, solving ill-defined & non-unique problems, and other work-related skills. Also, such experiences look well on resumes.

BOX 8 - Capstone requirements – discussion

Current EOAS courses that are capstone experiences include EOSC 445, the 6-credit project-based capstone for geological engineers which involves and ENVR 400, a 6-credit course that is research oriented and community-based.

Other EOAS courses include smaller-scale "capstone-like" activities, but a capstone degree *requirement* would expect more than a project for partial credit in a normal course. Currently in EOAS, the number of courses in which students engage in capstone-like experiences is summarized here, using data gathered from instructors and summarized on the learning tasks page.



Benefits and tactics of capstone experiences were generously summarized for the QuEST project by C. Hunter, curriculum consultant at CTLT, including definitions, types, purposes, benefits and keys to success. See Capstone Courses and Projects – An Overview, with 18 references.

UBC Strategic plan states that best efforts to transform education include "*...engaging students as co-creators of their education*". Capstone experiences are all about providing opportunities for students to take on some ownership of their own learning by tackling larger scale problems or applications.

The following are suggested tactics for implementing capstone experiences.

1. **A capstone requirement could be achieved** using any one of the following options (examples only): >>discipline-relevant work experience (eg, minimum 300 hours) or co-op workterm; >>an honors thesis,; >>a directed studies project; >>an existing course such as ENVR 400 or EOSC 445; >>a new pan-EOAS capstone course – although adding a course to a degree requirement is logistically challenging.
2. **Examples** of capstone experiences in the literature include undergraduate geoscience research experiences (Allen, J. et.al., 2020), a senior capstone seminar in mathematics (Atanasov et. al, 2013), and a project-based course series that prepares students for a mathematical interdisciplinary contests in modeling (Oremland and Szabo, 2021).
3. **Field experiences** in work, research or field course settings (eg EOSC 223, 328, 428, or 472) could count. Examples of external field learning opportunities include the SAGE program (Summer of Applied Geophysical Experience); see Jiracek et al., 2000) and the near-surface geophysics center, Comas et al., 2023.
4. **UBC examples:**
   - During their final year, most engineering students must complete a major, year-long capstone project. See https://engineering.ubc.ca/capstoneproject for details.
   - One example worth seeing (although at the master's level) is the UBC Master of Engineering Leadership Clean Energy Engineering Capstone Conference. There is no need emulate exactly at undergraduate level but aspects could be adopted and lessons learned applied.
   - The University Industry Liaison Office (UILO) provides capstone opportinities: see https://uilo.ubc.ca/industry-partners/capstone-projects.
   - The UBC Sauder School of Business also offers capstone experience.
   - UBC's Masters of Data Science also involves capstone projects.
5. There are likely many others – a simple search with "UBC capstone" yields plenty of sources for inspiration. **Contacting capstone project coordinators** would be a natural step for designing a capstone requirement for EOAS degrees, perhaps starting the the QES degree specializations.

3. Introduce student portfolios

This is a "good idea" that may be more challenging to implement. However it is worth considering pros, cons, opportunities and precedent.

BOX 9 - Student portfolios: pros, cons and precedent

Learning portfolios (electronic or otherwise) provide opportunities for students to gather a collection of **demonstrable skills** and resulting "**products**", and to **reflect periodically on progress** towards completion of their degree. They are useful additions to any resume as they provide the kind of evidence of maturation in a discipline that is not possible with just a list of grades. Use of portfolios would be consistent with the UBC Strategic plan which states that best efforts to transform education include "*...engaging students as co-creators of their education*".

Landi and Minden, 2023, describe the benefits of including learning portfolios instead of final exams in a mathematics course taught during the COVID pandamic by stating that "*Given the stresses that students faced during pandemic learning this final portfolio allows us* [instructors] *to view their growth as a whole and demonstrates to the students themselves their ability to learn mathematics*".

Literature on educational portfolios articulate benefits to students, but they seem "hard" to implement and sustain. ePortfolios were being explored by several groups at UBC between roughly 2010 and 2018 (presentation by L. Write, 2014) but enthusiasm seems to have dwindled after that. Programs such as business, nursing, teacher education and dentistry have all experimented with learning portfolios. Currently, the education faculty requires portfolios for pre-service teachers. In EOAS, ENVR 200 currently has students produce portfolios (although they are time-consuming to assess), and other units have either experimented with portfolios or included other opportunities for students to reflect on their learning.

"*Teaching portfolios*" are currently expected for faculty as part of the promotion process (see CTLT's teaching portfolio page). Students would also benefit from producing a permanent (ideally digital) record of progress and reflection, even if only in a reduced format. Full-on degree-wide students' learning portfolios may be harder to implement, justify, assess, and sustain for larger programs, but they - or some variation of them - may be attractive for specializations with lower enrollments or in individual courses.

4. A broader more impactful foundational course

A foundational course that **all QES students could or should take** would be a means of introducing students to the inter-disciplinary and quantitative nature of Earth sciences, and building a sense of community early in their curriculum. This would benefit both students and faculty, as well as graduate students and researchers if they are included in the delivery of such a discipline-spanning course.

BOX 10 - Describing EOSC 212

The course EOSC 212 currently meets one aspect of this goal; it is essentially an "*introduction to scientific thinking and communication*" with an engaging perspective and teaching environment. It was developed based on research about "scientific expertise" (Jones, Jellinek,& Bostock, 2012).

The settings for EOSC 212 modules change year to year but the "teaching model" is now over a decade old, so it may be time to leverage its success by considering options for updating it to

- meet more-broadly based objectives that introduce contexts and applications of quantitative earth sciences that go beyond the current research-focused perspectives, and
- engage more of the Department faculty in contributing to this (and other) introductory courses aimed partly at inspiring students to pursue earth science (especially quantitative) degrees and careers. More details are on the "Enhancing courses" page.

Specific suggestions include:

- A key to a broadly relevant introductory course would be to engage the community of Department faculty members more widely in defining, refining, and teaching such a course. Meetings about this issue could usefully follow agreement about Program Learning Objectives (see the "Enhancing existing degrees" recommendation page).
- An upgrade or design could start by identifying desirable capabilities (not concepts) that are consistent across the department and likely post-graduation occupations, and avoiding those that are more specialized.
    - This could be done using a simple survey based on skills identified in the preliminary 2019 discussions – summarized in this 1-pg table – and maybe others. Ask instructors if each skill is *critical*, *desirable*, of *marginal use*, or *never needed*. Consider also the concepts taught, determined by survey in 2020/21 and summarized here.
- Based on results, priorities meeting the needs of all participating specializations would be determined, then adjustments or a new course could be proposed.
- One goal would be to engage students in a broad view of the quantitative nature of all geosciences, including an emphasis on the impact of quantitative Earth sciences on individuals, communities, commercial sectors and the Planet.

4.5.3 Recommendation 8. Alternative perspectives on a QES degree

Radical change may not be appropriate at this time, however discussions about the longer term future may be worthwhile. Therefore, these suggestions are more like ideas or aspirations.

BOX 11 - Discussing alternatives and novel ideas

The rapidly evolving needs and opportunities of coming generations suggests a need to move beyond traditional post-secondary educational models. Notions being discussed more frequently at post secondary institutions include: • life long learning, • alternative credentialing, • increasing specialization of scientific disciplines, • diverging priorities of universities and non-academic sectors, and so on. These and topics are all worth discussing as the demand for post-secondary qualification continues to grow while knowledge, necessary skills, technologies and priorities evolve more rapidly than departments can keep up.

Are there differences between preparation for "**normal**" (i.e. traditional) **careers** versus preparation for **post-graduate research** degrees? One approach to addressing this apparent contradiction is outlined in Keane and Wilson, 2018. They suggest that occupational categories are evolving away from traditional disciplines because of greater integration of relevant (geo)sciences; "*The ideal result* [upon graduation] *will be a more integrated geology and geophysics portfolio of competencies*". They recognize that robust quantitative skills are still critical predictors of success, but that other areas of focus include:

- solving complex geoscience problems with AI, ML and data science;
- data acquisition strategies, including sensors, procedures and quality control;

- a growing demand for strong geologic cognitive problem solving.

Pros and cons of **considering all QES specializations as one "scientific discipline"** in the spirit of the American Geophysical union (AGU) have been discussed several times in the past. (AGU includes 25 sections spanning the physical Earth sciences, all dedicated to fostering scientific discussion and collaboration rather than focusing on concerns of industry.) This notion was articulated at the EOAS Departmental Retreat in 2019 by responding to the question: "*Are there any other specific opportunities to improve the specialization?*" with the following succinct response: "*Consider re-branding geophysics in the AGU context as including ATSC, Physical OCGY, Hydrology, planetary physics, etc.*". See the summary of pre-QuEST departmental deliberations. A complete overhaul of all quantitative specializations in EOAS to fall under one umbrella degree would be complicated. Doing so could also risk making the diversity of career and research opportunities even more invisible to prospective students. However, more radical ideas probably do deserve some consideration, if only to establish the tolerance and interest for such change within the Department.

One appropriate perspective is to re-imagine **STEM Workforce Development as a Braided River;** Batchelor et al., 2021 suggest that a contemporary approach to today's science careers could look less like a structured pipeline and more like a collection of paths that change and adapt to the needs of the individual. This has a JEDI (justice, equity, diversity, includsion) perspective which has implications for "marketing" available degree programs. It is also a generally intriguing way of thinking about curriculum and how it could evolve.

In terms of precedent, there are **creative degree options** at other peer institutions. For example, "Joint masters in applied geophysics" at the IDEA League of universities. Also, some institutions are considering the so-called **"modular" degree.** This means defining credentials based on capabilities achieved rather courses taken.

Specific suggestions include:

1. **An over-arching QES degree?**
    - Biomedical Engineering has an interesting model for its interdisciplinary, interconnected, collaborative and customizable BASc program. Students pursue one degree (BASc in biomed eng) but choose 3rd and 4th year courses to specialize in 1 of 4 streams: biomedical informatics, biomechanics & biomaterials, biomedical systems & signals, or cellular bioengineering. A capstone project course is required. This is a single degree with the four chosen threads not indicated on their qualification.
    - They (Biomed) have no trouble attracting students – many are hoping to get into med school. The degree also leads to clear, meaningful professional engineering qualification compliant with Canadian engineering accreditation requirements.
    - Perhaps we can keep the distinct degrees, but arrange their curricula in a manner similar to biomed eng, with common aspects, but specialized 'threads', which are in fact degree titles.
2. Consider an **optional QES stream within the ENSC** specialization involving existing EOAS courses.
    - Ensure it is characterized to attract and inspire appropriate students. Market research would be a good idea.
    - Determine if there could be QES components as part of the Faculty of Science's sustainability and ENSC ideas and aspirations. T. Ivanochko would be the first point of contact for such discussions. Her sabbatical (2023-2024) includes consideration of ENSC program's future.

3. Could students **achieve a program's goals (PLOs) in ways other than taking defined courses**? Examples could include open-education, external online courses such as the GIS course here or Python-based Earth science methods at Project Pythia).
4. **There may be efficient alternatives to conventional course structures.** For example, a course in which students students have increased agency could have 5 modules and the requirement to complete any 3 of the 5. This may be easiest to implement with online courses.
5. **'Badges', micro-credentials, course components;** these alternative or additional credentials could involve partnering with new sustainability, climate or environmental initiatives. Could students pursuing those credentials (ugrad, grad, or continuing ed.) receive some sort of credential for one or more courses? This approach is being actively promoted by Coursera for Campus, a for-profit group selling ready-made learning materials and courses for use at universities. This is NOT necessarily a route that UBC would want to go, but their sales literature does provide some inspiration about how to package and target career-preparation content. It is also good to know "what's out there" and what students may be finding as alternatives when they are deciding how to optimize their time spent in post-secondary education.
    - EOAS precedent is discussed in notes form here.
    - The commercial education sector is pursuing micro credentials as an opportunity. See for example the Coursera Ebook: "Advancing Higher Education with Industry Micro-Credentials".
    - See also their Ebook: The Professional Certificate Playbook.
    - micro credentials – as a means of serving educational needs of professionals (like M.Eng, and online certificates) and meeting students' interests in obtaining named credentials identifying individual interests and concentrations.
6. **Examples of creative synergies** between related groups –
    - A near-surface geophysics center for "convergent science". This is an example of like-minded academics identifying opportunities to leverage needs and expertise in small or "niche" disciplines into a larger initiative that will have a better chance of gaining momentum that if individual entities remained independent.
    - Shared field school opportunities – with other western schools. Precedent in the US – SAGE (although they have corporate funding).
    - Given sufficient time, a discussion with L. Lukes might yield insights about what other institutions are doing.

4.6 DEPARTMENT LEVEL RECOMMENDATIONS

These recommendations represent changes to the way the Department operates as a unit. Some represent a shift in "culture" and hence would require broad-based buy-in and support in terms of time and resources. Culture shift takes time and commitment.

4.6.1 Recommendation 9. Enhance and streamline faculty / TA support and development

For quantitative geoscience degree programs to become more **agile and flexible,** faculty need **regular** support to develop, maintain and assess relevance of courses and learning experiences. The diversity of skills and perspectives among EOAS faculty can be leveraged by addressing regular curricular review, not as individuals, but as a team, including research faculty, educational leadership faculty, lecturers, science education specialists, technical and organizational expertise, and the energy, enthusiasm and creativity of students at all levels. EOAS and UBC are already good at building effective educational development teams, and there is also educational research that supports and encourages such collaborations (Rozhenkova et.al., 2023, Weiman, 2017, and many others).

1. **Enhance QES researcher interactions with undergrads**:
    - **Cross-pollination** among EOAS disciplines: establish a "new tradition" or expectation of bringing guests to courses who can offer new contexts for existing content. Could be EOAS or other research or education faculty, lecturers, postdocs or grad students. Some courses already do this – especially ENVR which includes community and industry guests as integral part of core courses.
    - **Ask QES and other faculty** the following two questions, either as 10-min interviews, as an email feedback request or as a one or two question MC survey (including "other" option plus space to explain):
        - *How could we enhance the interactions your research group has with undergraduates? (Eg. present or showcase at courses, clubs, individuals, research opportunities such as directed studies, etc.)*
        - *How could you &/or the Department most efficiently showcase the importance and impact of research and other work done, to support recruiting, outreach and undergraduate learning? Such showcasing should be part of a marketing strategy.*
    - Maybe ask these questions twice – once as "what strategies are most likely to be effective" and then again as "which strategies would you be willing to contribute an hour or so of your time each year?"
    - See also suggested actions under student support.
2. **More regular and informative communication about teaching.** See recommendations in Fissel et al., 2022, which explored faculty preferences (frequency and medium) regarding communication with administration. See the "*Brief summaries of selected citations*" dropdown box at the end of this page.
    - **Regular opportunity to gather** – perhaps a 1-2 hr lunch once each year or each term? Something an SES could/should do, or a Teaching Initiatives Committee effort.
    - If not a meeting, then 15 min updates twice each term, even it that means faculty meetings that are 1.5hrs instead of 1 hr.
    - **An annual "teaching in our Dep't"** resource or presentation (ideally both) to keep everyone up to date with development projects, spotlight individuals or initiatives, offer advice on one specific topic (eg "best practices for syllabi") and enhance the sense of teaching as an evolving community activity. Include pointers to support (peers, Dep't (SES etc.), Faculty level (SkyLight), Institution (CTLT and student Careers support), each with names and contacts.
3. Address the **strain or challenges facing faculty** – especially the feeling of being over-extended (although tenured academic faculty are by nature exceptionally hard-working). This was recognized in the 2021 EOAS strategic plan, item U4 "*High Teaching Workloads*", in the "*Undergraduate Teaching, Learning and Educational Leadership*" section. Pautz and Diede, 2022, addressed faculty motivation and recommended steps for enhancing relationship between faculty and development people in the department, Dean's office and CTLT & Career Centre. See the "*Brief summaries of selected citations*" dropdown box at the end of this page.
4. **Professional development for EOAS faculty; possible workshops.** ProD opportunities (eg workshops) should be part of normal departmental culture, but keep them short/succinct. Offer as part of existing events. Using one faculty meeting each term (or year) would be a straight-forward "no-cost" solution. Who to deliver? Educational leadership faculty, lecturers and science education specialists, or bring in expertise from SkyLight, CTLT, Library or Career Services. Some suggested topics or tactics:
    - Increase everyone's understanding of **how people learn and become professionals** within a discipline – for both instructors and students. If both instructors and learners could keep such awareness front-of-mind, then choices of learning tasks would be more precisely targeted towards learning objectives, and a greater commitment could be anticipated cor carrying out those tasks with enthusiasm, diligence and honesty.

- **Syllabi and CLOs;** recommendations are on the Courses-level recommendations page.
- **Open education resources** (also here) and "publication" at CiRCle. These are opportunities to deliver legitimate "products" other than journal or conference publications into the public domain. Perhaps attractive to teaching professors and lecturers.
- **Fundamentals vs Career preparation** in existing courses, facilitated by Kimberly Rawes of Student Career Services.
- **Generative AI:** To use, or not, and how? Dep't should establish perspectives by engaging in discussion about this in teaching, learning and research. Consider the literature and insights from UBC colleagues who are committing time to thinking about generative AI and learning – eg SkyLight Lucus Wright at CTLT. A separate page contains a few further thoughts on generative AI, based largely on three 1-hr workshops about generative AI in teaching and learning facilitated by CTLT. Well worth exploring. See also the IEEE opinion piece on ChatGPT in education, Sinha, Burd & du Preez, 2023.
- **More generally,** it might be worth regularly identifying (or promoting) CTLT workshops as they arise (a quick job for SES personnel?) It is likely that many faculty members do not keep abreast of ongoing professional development opportunities. Perhaps an expectation could be established to participate (or present) in at least one or two each year?
- More **paired teaching** – to help with course transfer, communication among dep't teaching faculty and to inspire adoption of resources or tactics that work. Maybe the "official" paired teaching commitment is not needed but pairing up with the deliberate intention of sharing and transferring teaching and learning tactics is advised.

5. **Graduate student training** in geoscience teaching and learning as important for preparing future researchers and instructors in the basic expertise regarding "how people learn" and how to teach them. The precedent is well established in EOAS and at UBC more generally, and there is plenty of literature supporting the importance for adding expertise in learning as a graduate student outcome, such as Ruder and Stanford, 2020.
   - The EOAS course **EOSC 516,** "Teaching and Learning in Earth, Ocean and Atmospheric Sciences" is well established but it's teaching model can only support a limited number of students. This needs to be adjusted to accommodate more students.
   - Many graduate students who work as **teaching assistants** are exposed to teaching for the first time with little or no training at all. Especially in larger courses, a teaching assistant is the main (or only) personal connection that undergraduates can make, and asking TAs to serve that mentoring role with no training is like asking a faculty member to teach a course far outside their area of expertise without time to prepare. It is possible – but not optimal.
   - **Graduate supervisors** are advised to recommend taking EOSC 516 or something equivalent because future science experts need to understand how people learn about their discipline and how an expert can help novices learn about their discipline.
6. **Justice, Equity, Diversity and Inclusion** (JEDI) are currently front-of mind in many organizations. Actions taken towards enhancing curriculum, attracting students, and supporting faculty are all incorporating these considerations into planning and implementing.
   - While there is no intention here to diminish the critical importance JEDI issues, UBC and EOAS are visibly engaged in embedding JEDI considerations into all decision making. Therefore, the QuEST project did not focus on JEDI-related issues. However, incorporating career preparation into learning is as much a JEDI issue any. As explained by Ng, 2023, disparities in experience, family support, financial stability and other factors all contribute to disparities in outcomes, including success (or not) at gaining experiences beyond academics that will be meaningful on resumes.
   - Examples of sources: Cramer, et.al., 2021; current GSA diversity policy and activities on their diversity webpage; many articles in the JGE (Journal of Geoscience Education); UBC Faculty of Science EDI perspectives; EOAS EDI perspectives; UBC's equity stance and activities.

BOX 12 – Brief summaries of selected citations

Communication preferences - Fissel et al., 2022:
Survey data gathered at University of Central Florida (UCF), one of the largest universities in the country; survey, N=56 with a reasonable spread of faculty roles.

- Preferences for daily or weekly communications were
  - email (78.4%),
  - social media (50%),
  - University website (49%).
- Never send faculty-targeted communications through:
  - instant messaging (37.5%),
  - hard copy newsletters (26.7%),
  - Microsoft teams (26.1%),
  - UCF Mobile App (23.4%),
  - social media (16.7%).
- Potential practical suggestions for communicating with faculty are:
  - Faculty want information from a centralized location
  - Source matters. Messages from the department chair have weight and credibility
  - frequency, applicability, and channel are important.
    - consistent message frequency and channel will help declutter your information
  - don't sent to those who are not relevant. Be sure email lists are correct, current, and without those not needing the information. That means the provider of regular information should be able to assess and modify the list being used.
  - Regular (weekly?) faculty development information (like the EOAS weekly Friday blast).

Faculty motivation - Pautz and Diede, 2022:
Motivation: faculty are highly motivated in their work and are positive about their students. More specifically, respondents to the survey note that the intellectual stimulation and engagement that their work offers them motivates their professional lives (48%, the largest plurality). Further, three-quarters of respondents report that their academic work and professional interests closely align. Salary/financial benefits and other fringe benefits do not significantly motivate them, though some report teaching for free, an experience that they find insulting. In contrast to some prevailing perceptions, faculty included in this survey feel positively about their students: 65% agree that their students work hard, and 79% agree that their students are focused on what they are learning. Only a small percentage (11%) think that their students are unmotivated and lazy.

Evidence of strain: However, the survey results confirm that faculty are under strain. Respondents reported experiencing stress (72%) and fatigue (65%) in their work. Fifty-nine percent declared that they are experiencing burnout. When asked about the sources of difficulties in their professional lives, the largest portion of respondents (42%) reported workload inequities. The next most frequently cited challenge was the COVID-19 pandemic (37%). Additionally, 36% of respondents also indicated that budget and financial concerns as well as campus communication and transparency were sources of significant quandary. Rounding out the top five most cited difficulties was department environments or cultures (35%).

Faculty and educational developers: These professionals tend to hold student-focused learning as paramount, yet the importance of faculty energy and enthusiasm in their own learning and teaching is an often-neglected aspect of professional development.

4.7 STUDENT SUPPORT

Good support for students will improve the sense of community within EOAS – which is a prerequisite for an attractive and stimulating environment for working and learning. In fact, **UBC's strategic plan, Strategy 15,** is "*Student Experience: Strengthen undergraduate and graduate student communities and experience*".

BOX 13 - Why student support?

Peer institutions who are successfully improving their geoscience curricula agree (initiatives at peer institution are discussed on the Adjusting degree program page) that community building is a priority moving forward. Stanford in particular mentions the importance of social component of community building. Being a vibrant community makes a Department a visibly great place to study. It helps students clarify their expectations, gives them a reason to "look forward to being here", and can help promote career preparation, all without compromising the emphasis on learning the fundamentals and practicalities of their chosen specialization. The "costs" are a bit of time, regular opportunities to connect, and a commitment to maintaining a few key resources (such as the Canvas-based advising "course" for all students).

One important outcome of the EOAS student experiences survey (Jolley, 2020) is that they expressed a need for initiatives to address **stress management and well-being**. Geological engineering students in particular report significant challenges with the high course loads. This concern reflects an institution-wide (and in fact, global) challenging facing students today. Recommendations in this section are aimed at increasing active support for students. Their success depends on being able to focus their attention and energy on learning and practicing, without the burden of unnecessary personal or family stress.

One source of student stress is finding a balance between gaining rigorous understanding of fundamentals and preparing for the day they start looking for that first professional employment. For a short article with recommendations about **helping physics students prepare for the job-market** see Hirst and Benson, 2021. They provide insights about physics students' expectations, awareness of necessary capabilities beyond discipline-specific knowledge and skills, and strategies to help students (and those recruiting them), with the impacts of COVID, and a UK context, in mind.

Regarding student clubs, their **effectiveness and consistency of experiences** quite rightly depend upon the energy and maturity of the annual executives and membership. Recall that clubs have four goals: 1.provide a social setting for peers, 2. facilitate opportunities to learn from senior students and peers, 3. help bridge between school and professionals (eg via networking or conference events), 4. serve as a means of communicating with undergraduates.

EOAS is currently good at providing support in terms of space and some resources. That said, increased mentoring would result in more consistent benefits to students from year to year. This kind of support does not have to be onerous; it needs organization and infrequent but regular contact with both the club executive and the membership(s) as a whole. Interactions could happen perhaps once or twice a term, and perhaps on demand.

The following recommendations are aimed at increasing the success and well being of existing students and consequently making EOAS a highly attractive place to earn a degree.

4.7.1 Recommendation 10. Increase students' sense of community within EOAS & QES.

"*Undergraduate Community Experience*" was item U9 in the 2021 EOAS strategic plan, in the "*Undergraduate Teaching, Learning and Educational Leadership*" section. This set of recommendations as aimed squarely at this aspect of supporting students.

1. **Introduce (or adjust) an EOAS faculty service duty, to be called "Undergraduate Liaison"**. This requires a person who is interested in being a little more "hands on" with EOAS undergraduates. It is not about academic advising – that remains a separate task. There are lecturers or educational leadership faculty who would be good at this task so long as they are sufficiently resourced (time, access to staff & funding, etc.). Tasks that could be included in this person's mandate – or implemented some other way – include:
    - Maintain **resources** and offer **advice regarding scholarships, awards, bursaries** available to EOAS undergrads. The goal is not "spoon feeding" but equitable facilitation of opportunities. The Scholarships for geophysics students handout is a model for this kind of support.
    - **Actively introduce professional organizations** such as BCGS, KEGSF, BCGE, CSEG, SEG, and others. A student club executive member can maintain connections with such organizations, however, enthusiasm varies year to year, and the Department could help ensure these connections are maintained consistently from year to year.
    - Provide **information and Q&A sessions regarding program requirements**, including the distinction between majors vs honours, options such as co-op, minors or double majors, etc. This is nominally the domain of advisors, however offering events for all students more than just once in September would ensure that all students are equally well-informed and aware of options. It could also save advisors time by reducing the need to repeat 'standard information' in one-on-one meetings.
    - **Regarding honors degrees,** and based on discussion within EOAS about honours degree parameters in winter 2023, things can help define an honours program (differentiate it from majors) are:
        - More defined courses – a more targeted education, with more depth and perhaps more breadth as well
        - More higher level focused courses – more difficult courses, but not necessarily more 400-level courses (but that may be something to look at)
        - Some kind of research experience (449 thesis, usually)
        - Higher minimum GPA (perhaps only tracked for selective courses in the specialization)
        - The statement that Honours Degrees are the main path to graduate school is not accurate.
2. **Actively and regularly engage with student clubs** to
    - support and promote their activities,
    - help point them in directions to ease their interactions with the university bureaucracy,
    - encourage broader participation among all students, and
    - promote opportunities for undergraduates, graduate student, researchers and faculty to connect socially.
3. **Instigate a club or interest group that could be called something like the "quantitative Earth sciences interest group"**. This grouping should include all students in geophysics, atmospheric sciences and physical oceanography. Also, students in other specializations who may be interested should be invited. It would ideally be run by students like a new campus club, but faculty mentoring would certainly be needed to initiate and sustain it. Goals and activities would need to be developed but it could become a rewarding and creative "service duty" for the right faculty member.

4.7.2 Recommendation 11. Improve the efficiency and efficacy of QES program advising

1. Provide EOAS student **advising resources via Canvas**. In progress – see the Canvas Resource discussion page or the Canvas site itself (CWL required).
    - Action: Annually review and update advising guidelines on the Canvas advising site, or in some other form if the Canvas site is not used. Ideally in April soon after a term is finished.
2. **Advisors should consider interactions with QES students more as "mentoring"** rather than as simply providing advise about degree programs. For small programs, this can be both efficient and rewarding. Aim to be timely, regular, focused, and transparent (see "**Transparency of teaching practices**" on the Frameworks page).
    - Initiate regular (even if infrequent – e.g. once or twice each term) opportunities to "mingle" with QES students in a non-academic setting (see "*Increase students' sense of community*" above). Could be before a seminar, or after a class, or at an arranged mealtime event, etc.
3. **Honors students** could be better supported. Based on discussion within EOAS about honours degree parameters in winter 2023, things that can help differentiate an honours program from majors include:
    - Taking more defined courses – a more targeted education, with more depth and perhaps more breadth as well.
    - Taking more higher level focused courses – more difficult courses, but not necessarily more 400-level courses (but that may be something to look at).
    - A research experience (449 thesis, usually).
    - Higher minimum GPA (perhaps only tracked for selective courses in the specialization).
    - The statement that Honours Degrees are the main path to graduate school is not accurate. However, successfully completing an honours degree does demonstrate both diligence and (ideally) a successful introductory research experience,
4. Regarding **professional registration:** QES students have stated in surveys and personal communications that the requirements for being prepared for registering as a Geoscientist in Training in Canada **are not clear within EOAS**. Steps have been taken during QuEST and further recommendations for helping students understand and prepare for professional registration are included on the separate Professional Registration page.
5. Include support specifically targeting **preparation for post-graduation opportunities**. More details are in the Career Preparation page.
6. Finally, there is a page of **guidelines for instructors** (link to a summary) providing (and explaining) key resources related to undergraduate teaching and student support. This was derived from information provided to instructors by James Charbonneau (Faculty of Science Associate Dean, Students) at start of term in late August, 2023.

4.8 Career Preparation

UBC considers it a priority to address students' needs and educational strategies at the **intersection between academic disciplines and career development**. See the dedicated resource about "Career in Courses" (2023) prepared by the UBC Career Centre. (Contact is Kimberley Rawes, Manager, Career and Professional Development). Also in UBC's strategic plan, the words "career", "job", "work-integrated", "experiential" appear frequently. Preparing for rapidly changing and increasingly competitive world are certainly priorities at the institutional, faculty and departmental levels.

In this section, recommended actions are listed first, then some discussion is provided about balancing academic preparation and career development.

4.8.1 Recommendation 12. Incorporate career development into courses and curriculum

Some EOAS courses already do this in labs, lessons, assignments or projects. See figure 1 above, and discussion about *Current activities targeting career preparation* in the report on interviews from summer 2022.

1. **Make use of UBC's Career Centre.** They are eager to contribute workshops, presentations or materials to support inclusion of career-preparation components into existing courses and curricula.
    - They also offer students advice on interviewing, resumes, and other aspects of career preparation.
    - ENVR program includes a workshop given by them – ask Valentina.
    - Also, UBC's Career Learning in Classrooms page offers an introduction to tactics, resources and who to contact for assistance (K. Rawes, Career Educator and Manager, Career and Professional Development), including workshops for students that can be given as part of lessons.
2. Establish a **Department-wide** set of objectives and corresponding strategies for incorporating career preparation explicitly and transparently into courses and curricula (see "Transparency of teaching practices" on the Frameworks page).
3. **Adjust course syllabi, learning goals** and maybe even formal course descriptions to highlight how career-relevant learning is occurring next to learning goals that emphasize fundamentals & scientific values. Geophysics students have asked specifically for "*More industry-relevant examples, better connections with co-op options*" (Jolley, 2018). In fact, to quote McFadden etal., 2021, "*… targeted professional development could increase instructors' use of quantitative and data analysis skills to meet the needs of their students in context.*"
4. **Actively facilitate career exploration** (many ideas from day-2 discussions at the EER 2023 workshop). The goal is to introduce opportunities for students to learn about and reflect upon QES careers & how their learning and experiences at UBC relate to these options. Specific tactics could include:
    - Make at least one **required assignment** in each of the 2nd, 3rd, & 4th years (in any EOAS core course), that causes students to explore the EOAS Canvas student advising resource.
    - **One or more assignments** suitable for a second year course; see **two example activities** plus ways to adapt for EOAS.
    - Introduce a **careers seminar, workshop or bootcamp**. With alumni? (UBC-OK and others do this – ask C. Nichol.)
    - Consider having students incrementally build a resume or portfolio. This could be "required" or part of a core course.
    - A **career planning template** could be part of such an event, or an assignment or lab in a core course.
    - Weave **Linkdin** into career-prep activities. Search SERC for "linkedin" (79 results in Nov. 2023).
    - **Alumni** can be inspiring – but we need to access them more effectively than previous attempts. The "ask" needs to be clear, succinct and "easy". Surveys are "boring". Interviews are personal and meaningful, and a 30 minute zoom call should be "easy". The questions driving the interview need to be clear and answerable in 2-5 minutes each. Whether it is necessary to contact alumni through UBC's bureaucracy needs to be investigated. Single point of contact is quicker and more likely to be followed up. Accessing volunteer executives of societies such as BCGS could be a good starting point.
5. **Consider an official "course" or "for credit" career-development experiences.**

- Such an initiative is non-trivial but several schools are finding it worth while. Georgia Tech's School of Earth & Atmospheric Sciences is one example of a department that has committed to offering a 1-credit career development course.
- Impacts of a **purpose-built course** all about exploring career options in geosciences are reported in **Viskupic et. al., 2022**.
- **Egger & Viskupic** discuss similar initiatives at Central Washington and Boise State universities in their presentation with materials listed under "Tuesday" from the 3-day Earth Educator's Rendezvous, 2023, workshop.

6. Highlight the **importance of QES professions in terms of impacts on society**. This is "marketing", but such visibility should be included in core courses like EOSC 212, 350, and others.
    - Example of **why** is in "altruism in geoscience…", Carter et.al., 2021.
    - Example of **how** is in "Mapping geophysics to the UN sustainable development goals", Capello et al., 2021.
7. Suggested tactics for career development in G. Ng, 2023. For example, as an instructor, ask yourself:
    - What can I adjust easily to give my **students a greater awareness** of what's happening in the world AND how **they** fit into that bigger picture?
    - What can I adjust to give my students experiences they can **boast about** in future job interviews?
    - How can I give my students more opportunities to **build relationships** with non-academic professionals?
8. Incorporate aspects of **Justice, Equity, Diversity and Inclusion** (JEDI) into all career preparation activities.
    - Consider reviewing AGI's "vision and change" document (Mosher and Keen, 2021), which includes sections and discussions of **recruiting for a "diverse and inclusive community"**. "Diversity" and "diverse" are mentioned 50 and 47 times respectively in that report.
    - The engineering and geoscience professions have high expectations regarding every professional's attention to the importance and value of equity, diversity and inclusion (EDI).
    - Also, engage with local initiatives and aspirations – especially those being run by L. Lukes and S. Pete, and review the Faculty of Science EDI website.
9. Improving **support for students who need or want to register as professionals** within BC is the subject of a separate set of recommendations.

BOX 14 - Explicit career development as part of academic preparation

Why should we **actively promoting awareness** of geoscience (especially quantitative) career opportunities that encourage students to **reflect on** personal goals, preferences, priorities and progress? To quote Viskupic et. al., 2022, "*Undergraduates majoring in geoscience are often unaware of their career options beyond traditional resource industries; they need explicit support to consider their post-graduation options.*" …and… "*Being deliberate about exposing undergraduates to geoscience career opportunities may help to attract and keep students engaged in the field, and to graduate geoscientists who are more highly-qualified for the workforce.*"
Is it our job to include "job-training" along with teaching the scientific fundamentals that underly our own expertise? Ng, 2023 makes several relevant insightful points; it is well worth taking five minutes it takes this short article from Harvard Buisness review. E.g:

- "*Students today - your students - face "experience inflation," in which even entry-level jobs require previous work experience. The result is a chicken-or-egg problem; graduates need employment to prove themselves, and few employers are willing to give a chance to someone who is unproven. No wonder more than half of college students suffer from chronic stress.*
- "*You are more than an educator; you are a role model, a mentor, and a gateway to a better life.*"
  And more. This does not mean the answer to the question above is yes - we are responsible for

"job training. HOWEVER it does mean we are responsible for making the effort to weave opportunities for students to practice some of the behaviors, attitudes and habits that are going to help them succeed with the discipline-specific learning they encounter during their time as BSc students.

From the EOAS students' experiences survey in 2020, a key finding was that "*the ability to plan for the future and careers*" was a topic of wide interest and critique, except for engineering students. See both the **survey results** and the **Focus Group Results** sections of the summary prepared by Alison Jolley in 2020.

Resources related to career preparation include (also listed in the tools and resources table):

- Advising via Canvas: a Canvas "course" for all (or some) EOAS students with information about degrees, advising, career preparation and departmental activities.
- Exploring Careers: examples of career awareness and preparation initiatives
- Professional registration: why and how to efficiently ensure that interested students will be able to register as professionals after graduating.
- **Important:** before developing curriculum adjustments of any kind, be sure to review relevant section(s) of the UBC Guide to Curriculum Submissions for UBC Vancouver.

BOX 15 - Precedent regarding career preparation

What strategies do **instructors of majors-level geoscience courses** currently use to expose students to geoscience careers? Data representing a broad sample of US institutions was synthesized by Viskupic et. al., 2022, using data from 2016 first presented in Egger et al., 2019:

1. Make explicit connections between skills needed in the geoscience workforce and course assignments and outcomes (**64.4%**)
2. Include info. about geoscience and STEM careers and career pathways (**57.0%**)
3. Highlight alumni who work in geoscience (**52.4%**)
4. Give an assignment in which students explore geoscience careers (**9.1%**)

Interviews of 20 EOAS faculty with diverse backgrounds yielded results detailed in the report on interviews about teaching they use to support career preparation. Thirteen career preparation tactics were identified from these interviews. This figure shows the degree of consistency or agreement among EOAS interviewees.

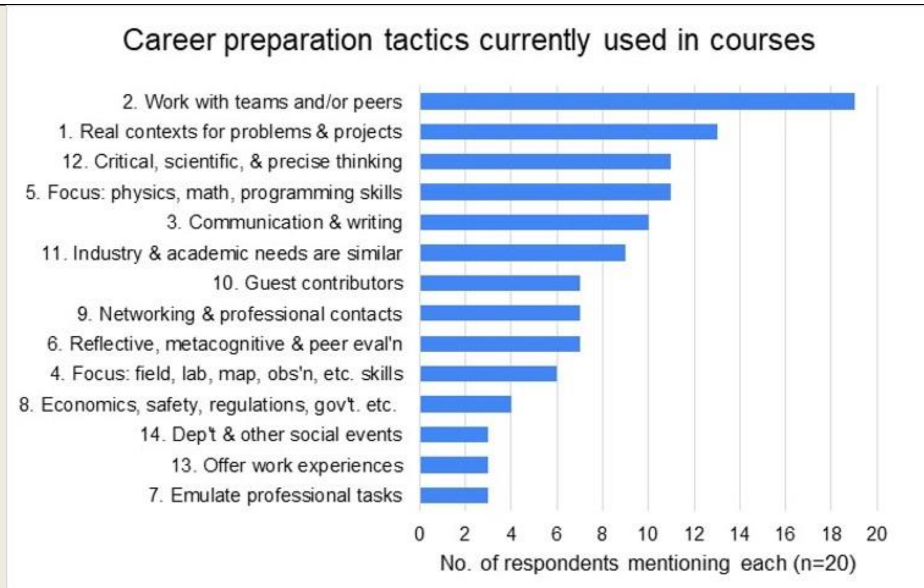


Figure 1. *Summarizing the number of respondents who mentioned they use each career-preparation tactic in their courses. Numbered tactics correspond to Table 1 in the report.*

There are notional similarities between points 1-4 above and the 13 EOAS tactics. The main difference is that EOAS faculty focused on "teaching tactics" whereas the points from Viskupic et al. 2022 are about ways of exposing students to career settings *other than* those integrated into courses and teaching. **EOAS interview results** are particularly interesting when interviewees are distinguished based on whether the individual has (a) had industry experience or research partners or (b) has a purely academic background and research contexts.

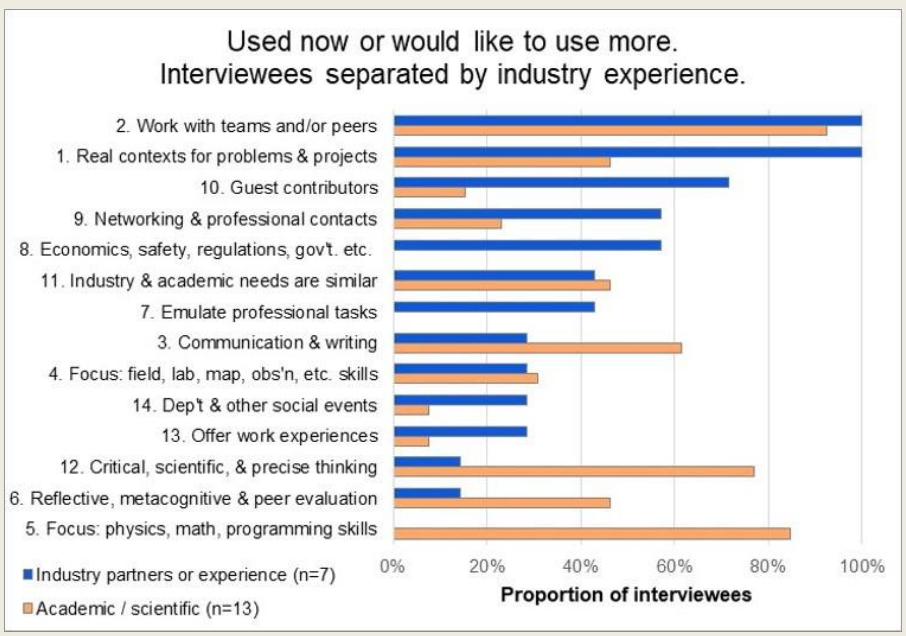


Figure 2. Comparing interviewees with industry experiences against those with primarily academic experience. Proportions of each group are used to illustrate the extent of agreement among interviewees in each group. Results are illustrative only as no significance tests have been applied. Numbered tactics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

Zero or one of the faculty with purely academic backgrounds mentioned these tactics as important for supporting career preparation:

- Emulate professional tasks
- Economics, safety, regulations, gov't. etc.
- Dep't and other social events
- Offer work experiences

Also, zero or one of the faculty with industry background mentioned these three tactics as important for supporting career preparation:

- Focus on physics, math, programming skills
- Reflective, metacognitive & peer evaluation activities
- Critical, scientific, & precise thinking

These and other differences in perspectives (see the report for details) suggest that the students might benefit if the department worked towards establishing a collective set of strategies for incorporating career preparation much more explicitly and transparently than the current, ad-hoc approach that depends on an individual instructor's personal perspectives. Hence the list of ideas below.
Desirable ***skills*** for QES graduates have been detailed using three categories in our separate desirable skills report, and summarized on the desirable skills page. But what exactly do "career preparation ***tactics***" look like? To quote A. Egger from the job preparation workshop at Earth Educator's Rendezvous, 2023: “*How can we help students become aware of their career options, recognize and reflect on the skills they are learning, and make plans to achieve their career goals?*“ Many creative ideas were gathered there, collected in 11 categories in the workshop's GoogleDrive folder.

- There is plenty of **literature on this subject** and institutions are increasing the variety and quantity of support opportunities to help students with choosing specializations, job searches, and preparing themselves to enter the increasingly competitive workforce. At UBC, see the UBC and community experience section of the UBC Student Services home page, and especially the UBC Career Centre.
- For an annotated bibliography about **career preparation in math courses** and programs see the report generously prepared for QuEST by K. Rawes. It includes a framework for HOW career preparation can be embedded in a degree experience.
- Several good **workshops related to career preparation** in geoscience courses and programs were run in July 2023 at the Earth Educator's Rendezvous 2023 meeting. Corresponding **resources, references and outcomes** are cited on our reference page under Websites and resources.
- See also two examples of **initiatives enabling students to explore** geoscience career options and opportunities at other institutions, with suggestions of adaptations for EOAS.

4.9 Professional registration

These are concrete recommendations to enhance support for QES students aiming to register with EGBC as geoscientists in training.

4.9.1 Recommendation 13. Improve support for professional registration

Engineering students already are well supported, and geology students also have support. To enhance support for QES students, the following six recommendations were derived partly from the work of Prof. Craig Nichol (Dep’t EEGS, UBC-OK) and presented to the CCCESD in Oct. 2022 (meeting summary PDF). Conversations with geophysics students and a meeting with EGBC officials also contributed.

1. Appoint a **Professions Advisor,** ideally one person for all and who can liaise with EGBC.
    - This person should be added to the CCCESD website, this to be provided to Geoscientists Canada. Needs discussion and approval in EOAS.
    - Also maintain connections with CCCESD and Craig Nichol.
    - Identify the liaison person at EGBC.
    - Recommend annual meeting to upate changes at EOAS and at EGBC.
2. Clarify **student advising strategy** regarding professional registration. Leverage Craig Nichol's (UBC-OK) report on best practices for student advising regarding professional registration, presented to CCCESD, Oct 2022. See **Nichol, Craig, 2022**.
    - **Progress:** an advising spreadsheet has been prepared as a first step (Aug. 2023).
    - **A Canvas** site for EOAS has been prepared for demonstration (Sept 2023). See the discussion page or the Canvas site itself (CWL required).
3. Prepare and submit for vetting a **selfcheck list for geophysicists** that aligns EOAS courses with EGBC requirements.
    - **DONE:** – currently being vetted by EGBC (November 2023). Contact there is Vicki Charman <vcharman@egbc.ca>.
4. **A slight adjustment to geophysics degree requirements** would help students meet the geology requirements in EGBC. This would clarify NECESSARY courses and replace redundant courses with others. Geology is an important "missing piece" in our geophysics degree, so consider adding some or all of courses EOSC 220, 221, 222, and 223 (in that order) to the requirements – or as "highly recommended". For students NOT wanting to satisfy profession registration requirements, options could be accepted, such as more physics, math, ocgy or atsc.
5. **UBC's career Services** should eventually be appraised of the results of mapping UBC degree specialization course lists against EGBC requirements.
6. **Other EOAS disciplines** would benefit from notes regarding preparation for gaining professional status. This information belongs in the proposed Canvas advising site. Explore relevant orgnaizations such as https://eco.ca/, perhaps starting by asking C. Nichol for advice.

These next boxes discuss **(A) Relevance;** a summary of why it is important to prepare students for registration as professional geoscientists in BC, **(B) Ongoing Activity,** an outline of activities in progress as of Fall 2023, and **(C) Comments about geophysics** courses.

BOX 16 - A) Relevance

Over 80% of EOSC B.Sc. students aim to enter the workforce upon graduation. In particular:

- Only 18% of respondents said "grad school" or "research" (not counting engineers) when asked about intended careers (Jolley, 2020);
- 80-100% of respondents in engineering, geology, geophysics and atmospheric science programs intend to register as professionals (Jolley, 2020);
- geophysics students explicitly asked that EOAS "provide opportunities to meet EGBC requirements (Jolley, 2018).

In addition, the AGI's Status of Recent Geoscience Graduates, 2021, states (pg. 57) that in the USA, "*deficiencies in formal professional credentials are a challenge for recent graduates in securing employment*".

It is the Department's responsibility to ensure that our graduates are as well prepared as possible for their entry into the workforce, within the "normal" set of credits required for a BSc Major degree, and within the normal anticipated time-frame of 4 years.

Guidelines are needed to articulate the scope of support provided by the Department, and to ensure students can properly prepare for corresponding careers. Guidelines need to be visible – and promoted – so that prospective students (and their parents) can see benefits & rewards, and set appropriate expectations.

BOX 17 - B) Ongoing activity

1. A department-wide **advising and student information resource** is being built for deployment as a Canvas "course" into which all students can be registered. It will provide basic information that program advisors need to convey to all students. Details about professional registration are part of this resource collection. See the Canvas-based resource page for details.
2. For **prerequisite and course dependencies** with names, descriptions and links to UBC calendar, see our interactive course map.
3. **Mapping EOAS courses onto the EGBC requirements list**: with the help of Craig Nichol. (UBC-OK), information is being prepared for students and advisors to ensure that students are qualified for professional registration upon graduation. Corresponding tasks completed include:
    1. **UBC-V geology** courses have been mapped by James Scoates onto EGBC's Geology Checklist for Self-Evaluation.
    2. **UBC-V geophysics** courses have been mapped onto EGBC's Geophysics Checklist for Self-Evaluation. Results have been discussed with M. Bostock (Aug 2023), and they should be consistent with the Geoscience Knowledge and Experience Requirements for Professional Registration in Canada.
    3. A **blank EGBC geophysics** students' self-check list is available here.
    4. EGBC also has a 4-pg Guidelines document.
4. To support **advising and student planning**, a spreadsheet table with the Geophysics specialization course list from the UBC Calendar has been prepared to help students track courses they take against Faculty of Science graduation requirements and EGBC professional registration requirements. This table is provided here as a one-page PDF, or can be obtained as an MS-Excel spreadsheet from F. Jones.

BOX 18 - C) Comments about geophysics courses and EGBC registration

Here are thoughts and comments arising from mapping the requirements and options from the UBC academic calendar for a BSc in Geophysics against the EGBC "self check list" (see this spreadsheet here). NOTE these comments are **not** about the intrinsic worth or value of any particular course. They specifically target requirements for students (the majority) who will need (or want) to register as professionals in BC.

1. For professional registration as a geophysicist, EGBC requires 4 "Foundational Geoscience" courses – i.e. basic geology. This is not only sensible but desired by students and employers, based on conversations with both, and survey data from geophysics students: EOAS Geop survey report, 2019.
2. The EOAS geophysics degree has NO formal required applied geophysics course.
    1. EOSC 350 is only "recommended". It should be required as it is the only "exploration" course at UBC. (Although, see notes about EOSC 454 below.)

2. Calendar note 10 "Students interested in a career in exploration geophysics are encouraged to take EOSC 350 or PHYS 301" makes no sense – these are nothing like equivalent. EOSC 350 or EOSC 454 will be much more correct, and one or both should be required.
3. EOSC 454 is being reintroduced in the 2023-2024 teaching session. Depending on goals, it could work for GP-C24, "E&EM methods", or GP-C46 "EM theory", or FGP-A4 "exploration geophysics".
4. Field experience is required – EOSC 223 is the only thing that seems to make sense, unless a work experience can be applied. But it requires EOSC 221, which requires EOSC 220.
5. EOSC 212 has only **marginal** application in EGBC as GP-C05, "Global geophysics". ALSO, it is not a prerequisite for any other courses in the 2023 Geophysics calendar.
6. EOSC 250 has only **marginal** application in EGBC as GP-C41 "Calculus" or GP-C58, "Vector and tensor analysis". It is a "One of" prerequisite for 352 & 410. The EGBC list has no "fields" or "fluxes" category.
7. MATH 317 "Calculus IV" is required for geoph degree, but overlaps with EOSC 250. For EGBC there seems no place for it except same items as EOSC 250.
8. EOSC 410 can probably be applied for GP-C22 "Analytical Methods", or GP-C54 "Numerical Methods or Computing".
9. EOSC 450 may be only **marginal** as GP-C25, "Gravity & Magnetics".
10. EOSC 453 only **"sort of"** fits FGP-A2 "Global geophysics or physics of the Earth".

5 MARKETING: ATTRACTING & INSPIRING STUDENTS

QuEST goal 5: Initiate actions and recommendations to **recruit, retain** and **inspire** students with quantitative interests and capabilities.

The EOAS department wants appropriate potential students & parents to find and recognize the opportunities and rewards of pursuing quantitative science degrees within the Earth, ocean, atmospheric, planetary, environmental and climate disciplines. Making these opportunities more visible and attractive has been a Departmental priority since before the QuEST project was instigated.

Actions taken or ideas proposed in these sections target either **potential** students to support recruiting or **existing** students to inspire and support their preparation for life after graduating.

These two targets sometimes overlap. For **example**, increasing the motivation of existing students should result in word-of-mouth endorsements reaching prospective students who are choosing degree programs. Also, showcasing important, timely and rewarding occupations will support career preparation for existing students and highlight the diverse opportunities to available to students who could choose to pursue QES degree programs.

Initiatives targeting either of these two targets will also result in outreach opportunities that will benefit the Department's public relations initiatives.

5.1 MARKETING ACTIVITIES

Current or completed QuEST project activity aimed at inspiring potential, prospective & current students. See the introductory marketing page for goals.

This table of **activities** and **accomplishments**, ordered by date, is an outline only. See links within the table for further details.

No.	Item	Type	Description	Date
14	**LMS-based student communications resource**	Canvas 'course' Discussion	Based on success at UBC-O's EEGS dep't, EOAS will **pilot a Canvas 'course'** to support advising of all EOAS undergrads. It aims to improve communication about dep't activities, degree programs, expectations, preparation for careers and so on. A complete first draft was reviewed by a few EOAS faculty by November 2023.	Aug 2023
13	**EOAS/climate context in Math courses**	small TLEF	• Small TLEF grant awarded to Math Dep't ("strongly supported") : "**Math and EOAS Collaborate to Improve Climate Education at UBC**". Proposal prepared by T. Ivanochko, with Math Prof. Sven Bachmann as P.I. • **Team**: 10 from Math, 5 from UBC-O math, 7 from EOAS (including QuEST personnel) 2 from UBC Sustainability Hub. • **Goal**: incorporate EOAS & climate contexts into 1st yr math courses to (a) provide relevant and inspiring "purposes" to the learning of mathematics, and (b) expose students to the potentials and rewards of quantitative EOAS degree specializations. • Climate primer **workshops** delivered in summer 2023, and preliminary math assignments prepared by Math faculty and students for fall 2023.	May 2023
12	**Showcasing climate in SCIE 001**	Partnering	**Guest lecture** delivered in Feb. to pilot EOAS context in SCIE 001. S. Schoof (EOAS) presenting. B. Marcus (Math) professor.	Feb 2023
11	**Advice on curriculum rejuvenation**	consult	From **CTLT** (C. Hunter): support re. curriculum, curricular reform, peer institutions, syllabi, capstone experiences, interviewing & analysis procedures	during 2022
10	**Advice on career preparation**	consult	From UBC **Career Services** (K. Rawes): insights and support related to career preparation and job prospects	during 2022
9	**EOAS/climate context in Math courses**	G-Doc	EOAS & Math to cooperate on building climate context math courses. TLEF submitted by T. Ivanochko with 10, 3, 5, 2 partners in math, eoas, ubc-o, sustain respectively. C. Schoof	Nov2022
8	**Showcase QES professionals**	Web pgs	Showcasing professionals; arranged with UBC Science Alumni (K. Duffel). 14 alumni asked, one responded. One example profile page was built.	Sep-Nov 2022
7	**Updates to EOAS webpages**	Web pgs	• QuEST the EOAS WebSite crew update 8 pgs in the Undergrads section. Pages cover: >Why EOAS , >Career pathways , >Degrees , >Student Life and events , >Awards, Scholarships & Jobs , >Academic Advising & Support and >Student Achievements (which still needs current theses, projects etc.). • Update to Drupal 9 planned for end 2023. QuEST continues to contribute advise. Updates above are included, and look-and-feel is improved.	Sep2022

6	**Showcase student accomplishments**	Docs from summer 2022	Ideas for a framework to celebrate student accomplishments. Ideas were considered impractical, but for alternatives see "Celebrate current strengths more visibly".	Sep2022
5	**Industry contacts**		36 listed as of 220926, mostly via LinkedIn, and several alumni. See "alumni" recommendations.	Jul2022
4	**EOAS advertising flyer**	image	First draft only, but maybe a starting point? (Constructed using the online "Canva" tool).	Jul2022
3	**Jobs available** to QES students	G-sht	Initial compilation of 8 jobs available to QES students. To be augmented with a wider search if time permits.	May2022
2	**UBC web page updates**	Web pgs	• Adjustments to faculty of science Co-op work term opportunities (students and employers) • Adjustments to Faculty of science "What can I so with a B.Sc. degree?" • Adjustments to UBC programs descriptions: geoph, ocgy, atsc.	Apr2022
1	**Job Posting Analytics; various**	Docs	• Several search results to characterize skills required across disciplines, generated using the EMSI (now "Lightcast") labour market analytics and BC Labour statistics services. Done for QuEST by Carrie Hunter (CTLT). • See also Coursera Global Skills report (annual).	Apr2021

5.2 A FIRST YEAR Q.E.S. COURSE

The notion of a first year course for students with math, physics and computing interests and abilities has seen a fair bit of casual discussion among EOAS faculty. It was hoped that development could begin in 2020 but progress stalled perhaps due to resources and energy being overwhelmed by COVID-related priorities.

This page has two parts: first there are recommendations and associated discussions about how to develop a first year course, what its content could be and how to teach it. Then a synthesis of early discussions that about this idea is provided.

5.2.1 Recommendation 14. Develop a quantitative EOAS first year course

Recommended actions and tactics are organized into three categories; (1) development, (2) content, and (3) teaching models.

1. Regarding development of such a course

1. **Such a project needs a complete proposal** and a funding request (eg small TLEF).
2. Regarding **name and marketing of such a course**: make sure it has an "*eye-catching*" public face. Maybe "*Introductory Climate Physics*" is the wrong title since it seems daunting. It may be "true", but the truth also needs to be attractive.
3. The team:
    - A **dedicated project coordinator** is needed. UBC's course development support resources should also be engaged to minimize EOAS time and resources.
    - A **team of faculty** needs to be given time and space. Ideally, the team should be approved by colleagues so everyone's interests are represented.

- Factor **regular progress updates** (eg at Dep't meetings) and **opportunities to contribute** by interviewing, asking for content, etc.
- Include undergraduate and graduate **students** as partners in the development.
- Consider consulting with Sun Kwok if he is interested, able and still around.
- **CTLT** (Carry Hunter) is eager to support research for and development of such a course.

4. **Support** in terms of teaching/learning expertise, project coordination and teacher buyout during development. This won't happen without it becoming a "formal" EOAS project, with broad approval across the Department.
    - Take advantage of **UBC's course design** resources and expertise. Individual support is available, there are workshops on course or instructional design, and there are many resources with advice and wisdom from educational design experts.
5. Designing a first year course from scratch represents a significant opportunity to **incorporate proven best-practices** to optimize student motivation, efficiency & efficacy of learning, and instructor motivation. Some examples to consider:
    - **Unlike other EOSC 1xx or 31x courses**, the target audience for this course is NOT "everyone". It is a class size of perhaps up to 50 students interested in challenging, inspiring and relevant science.
    - **However**, students will expect to do well and they will not register for this elective if it gains a reputation for being "difficult". Students do not like courses that drag their averages down. This may be a reason to consider this idea as a 200-level course, and/or possibly as a prerequisite in some EOAS programs, but these have not been discussed.
    - Put careful thought into **teaching model**. Lecture? Flipped course? Single instructor? Sequence of multiple instructors (not recommended)? Paired instructors to support transfer in subsequent terms? Rotating teaching assignments or one (or two) faculty to take "ownership"? Modular?
    - Make it **attractive and fun to teach** so all EOAS faculty members will enjoy teaching the course. That means incorporating at least some room for instructor's "autonomy".
    - Keep it **straight forward** – no fancy or unusual scheduling or pedagogic needs.
    - Take advantage of the large **global community of educators** who teach geoscience "first-exposure" courses, especially NAGT and the SERC repository of geoscience teaching wisdom. Then adapt to the EOAS context.
    - Include **experiential opportunities** – lab visits, industry connections or field trips, career opportunity search assignment, and others. Maybe one for each module. Experiences could involve "virtual" experiences.
6. The goal should be to **not** to teach facts, figures and procedures about Earth and climate, but to **gain familiarity** with quantitative *ways of thinking* needed to understand how Earth works, and for sustainable, responsible stewardship of our planet and its resources and environments. Do not duplicate what goes on in MATH courses these students will already be taking.
7. Consider **precedent** from other institutions.
    - Consider especially ideas regarding first year courses from SERC and the EDDIE Model (Environmental Data-Driven Inquiry and Exploration) for quantitative modules in earth science courses.
    - See also the **global community of educators** who teach geoscience "first-exposure" courses, especially NAGT and the SERC repository of geoscience teaching wisdom.
8. **Determine likely students**; this is necessary due diligence or "market research" regarding who can, and who might, take this course.
    - A challenge when BSc students are the target is that first year students have no room for a "new" or "elective" course because they are way too busy taking prerequisite courses in math, physics, chemistry and communication.
    - First year electives are often taken by more senior students as electives. Whether to, and how to, mitigate or manage this needs discussion.

- Estimate how many students could (or would) enroll. CTLT can help with questions such as this.
- Determine potential student demand: For example, find a willing professor in a mandatory (or popular) first year course taken by appropriate students and ask them to complete a very quick 2 or 3 (carefully crafted) questions to gain a sense of interest, likelihood of taking such a course, and reasons for being *unable* to take it.
  - Do not ask students "*what would like to see or learn*". Asking "*if such-and-such an opportunity was available, would you be interested*" – or "*would you have been interested*" if we ask senior students.
  - Frame the proposal (to students) based on societal needs, by referring to quantitative nature of sustainability, environmental and resource stewardship, water & climate crises, etc. Mention "cool stuff" – measurements, analytical potential, meeting the needs of society, solving critical problems.
- Note there is already insight about impacts of current EOSC 1xx courses on decision making among EOAS graduates in the 2020 report by Jolley, summarized here. In short, the question and answer was: "***Did EOSC 1xx courses influence your choice****? 30-40% of Combined Majors, EOS Majors and Geology students said "yes", fewer than 10% for others*".

2. Regarding scope of coverage and content themes

1. Here are two models for **developing course module content**. The second is likely to be more inspirational.
   - Introducing **concepts** from math, physics and data science and **illustrate** them with applications, OR
   - First introduce **issues, questions, or problems** that are important for communities, scientific advancement, and understanding how our planet works. THEN explore the universal **concepts** from math, physics etc. are employed to measure, analyze, model, inform critical decisions, and understand the processes.
   - **Iteration or back-and-forth between the two models** is likely as course development seeks to clarify the inspiring contexts and applications versus ensuring that "desirable" concepts are touched upon.
2. Build a **modular course,** to be taught as 4 modules (not more). Four modules allows for ~3 weeks each with 9hrs of lessons and ~18hrs homework (if students take 5 courses and work 45hrs per week, they should devote a average 9hrs/wk/course, or 3hrs lecture + 6hrs homework). Four modules works well for DSCI 100.
   - Commit to **adding** a module every year or so to ensure the course remains current, and give faculty who are new to the course a chance to contribute a module that reflects their expertise and interests.
3. Design content and learning activities that **point at QES programs, courses, & experiences**. In fact, identify *explicitly* what inspiring learning experiences students can expect in EOAS courses.
4. Content and contexts need to be **inspiring**. See for example Capello, et.al., 2021, "*The Geophysical Sustainability Atlas: Mapping Geophysics to the UN Sustainable Development Goals.*"
5. **Jupyter Notebooks** are attractive because they facilitate interactive exploration of concepts at any level of complexity, from no coding at all, through modifying lines or segments of code, all the way to building or illustrating complete programs. Also they are becoming widely used across EOAS (and UBC) for both teaching and research, which makes it more likely that (a) EOAS faculty can pick up the course (or part of it) with minimal preparation and (b) students will either be familiar with tools or will be using them later in their degrees.
6. Course developers will benefit from exploring the large **global community of educators** who teach geoscience "first-exposure" courses, especially NAGT and the SERC repository of geoscience teaching wisdom.

7. Potential **themes** were discussed.
    - A "physics of climate" theme was originally a top choice. It is topical, students see it as "urgent" and EOAS has a wealth of expertise both directly and indirectly engaged in climate-related teaching and research.
    - An alternative suggestion (perhaps less "politically" charged) was "**Critical problems in Earth and Climate Sciences**".
    - The notion of "**spheres**" (atmosphere, ocean, hydrosphere, cryosphere, surface, etc.) as a framework was suggested. This may be a convenient way to describe the components of the Earth system. **However,** being somewhat abstract, to may be less attractive to students. They are attracted to topics to which they can relate; topics that they perceive as meaningful. The goal of the course is to attract and then inspire students, not "tell them" about the Earth as cleverly as possible.
    - With a little creativity, the teaching goals of experts (instructors) can be met regardless of the framework, but the framework will either attract students – or not. See also What is likely to be attractive above.
    - There is room for discussing the Earth science focus – whether climate related, "critical Earth science problems", Earth's spheres, or something else.

3. Regarding teaching models

1. Choosing **teaching tactics** (few vs many instructors; Jupyter notebooks or not, labs or not, etc.) is a second step. A focus is needed, best articulated by starting with 5-8 preliminary Course Learning Outcomes.
2. Regarding the **choice of teaching model**
    - A course such as this must be efficient to teach, sustainable and "transferable" (from one instructor to the next).
    - Efficiency and consistency are increased by a tightly scripted course (like early math courses) while the second approach is preferred by those who claim they "can't teach from someone else's materials".
    - Balancing efficiency and consistency while enabling some degree of autonomy is surely possible. Support from experts in educational design will be important.
3. **Single, two, or many teachers are options**. Jones and Harris, 2012 discuss pros and cons of these models. But having two teachers who truly work as a team, and bringing in a guest for each module, would effectively balance the competing objectives of efficiency, variety, exposure to EOAS, sustainability, and – importantly – transferability (from one instructing team to the next).
4. Traditional **lecture**, online, a truly **flipped class** involving pre-readings and classes mostly involving student activities (solo, pairs and groups) with minimal "lecturing", or **a hybrid**?
    - Note that if the intent is to rotate instructors then an effective way to ensure consistency with some autonomy is to use a paired-teaching model in which instructors teach in at least two subsequent terms, so they learn the ropes in their first term and mentor the next instructor in their second term.
5. **Labs are considered awkward,** hard to coordinate and probably unnecessary for a course like this. That said – EOSC 111 could have new modules developed to complement this new course.

The following is a summary of early paper- and email-based discussions about a quantitatively oriented first year course.

BOX 19 - Summary of early discussions

The rational for considering such a course were outlined, then initial "start-up" or "scoping" questions were posed regarding purpose, scope and structure, and then some initial ideas were discussed. The ideas are incorporated into recommendations above.

Rational

- EOAS aims to "revamp" quantitative Earth science degrees to be more reflective of "geophysics" in the broadest sense of the word - encompassing disciplines addressed by the American Geophysical Union (AGU). See the Early Priorities page for details.
- Building a quantitative Earth science first year course was considered one strand of this aspiration, but also appropriate in its own right since few existing EOSC service courses reflect the diverse and quantitative nature of the Earth sciences generally and the Department's expertise specifically.
- Such a course could serve as a UBC Science Breadth requirement, targeting students with math, physics or computing interests and "competing" with "astronomy".
- The course must be **sufficiently *inspiring* to recruit students** who wouldn't otherwise know they can gain rigorous, widely applicable capabilities by pursuing an EOAS degree. it should not be simply about basic fundamentals.

Questions posed regarding scope and format

- **What is likely to be attractive?** What can be built upon later?
    - In fact, "building upon" such a course may be an inappropriate goal unless any EOAS courses decide to make this new course a prerequisite.
    - What **concepts, methods, tools are students learning in first year** (or did they learn in high school) that we could leverage, amplify and illustrate with Earth Science examples?
    - Or - more appropriately - **what issues, problems, opportunities will attract students** to take the course? Not "math" - but something they feel as personal, something they consider important. The very successful ATSC 113 took that approach when it was designed. It is essentially "Weather that affects skiing, sailing and flying".
    - This is why "**Climate physics**" is better than "Earth system science". A focus that is meaningful to ~20 year-olds is needed, not something abstract.
    - Another suggestion was "**Critical problems in Earth and Climate Sciences**". This emerges from student feedback from questionnaires for the Climate Change credential / certificate working group which questioned the possible “left-ist agenda” of a climate change focus.
- **What assumed capabilities?** Do we assume first exposure to Calculus? Some exposure to writing code? Grade twelve physics?
- How to represent the **Department's breadth expertise** with only 3-4 modules? Or if that can be avoided as a goal, development choices would be easier.
- What should be the scope of coverage, principle subject theme and other aspects of content? This is discussed in a "scope" section below.
- What **teaching model?** What teaching tactics? What learning experiences? (Also detailed below.) Also, how to balance competing preferences for a "scripted course" versus one that instructors can teach "their own way"?

5.3 MARKETING RECOMMENDATIONS

QuEST goal 5 was to "*initiate actions and recommendations to* ***recruit, retain*** *and* ***inspire*** *students with quantitative interests and capabilities*". Marketing can be labour intensive and expensive. Departments do not habitually consider "self promotion" or "marketing" as part of their mandate. However if recruiting into QES programs is a priority, then "visibility is everything" and effort must be expended to make progress.

The recommendations in this section are for marketing actions that could be taken in 2024 and beyond. Actions already taken as part of the QuEST project are summarized in the marketing activities page.

The EOAS Department has realized this and has committed personnel and resources to communications and public outreach activities. The communications team is certainly well-occupied and these marketing suggestions are not meant to say their priorities should change. Instead, consider them as starting points for discussion about how priorities could evolve.

Since "marketing" takes time – and a particular point of view, it may be worth considering increasing the resources for the communications team, and/or partnering with the Faculty or UBC on specific marketing initiatives.

5.3.1 Recommendation 15. Establish a sustainable marketing strategy

1. The Department would benefit from **additional dedicated support** for marketing activity because suggestions in this section can be labour intensive. A few work-learn students, especially during summers when they work 20hrs/week) would be a good start. As of fall 2023, this challenge is recognized and students are contributing in various roles. However, a new set of priorities with recruitment high on the list would improve the visibility of, and enrollments in, Quantitative earth sciences – and other EOAS degree specializations.
2. **Add a QES faculty member or graduate student** to the EOAS communications team and give them a mandate to focus on QES outreach and recruiting priorities.
    - There are many current (fall 2023) outreach activities but few have any relationship to the quantitative disciplines, except perhaps activities related to climate and climate change.
    - If attracting students into QES degree specializations is a departmental priority, then public relations and outreach activities should reflect this priority.
3. A marketing **vision** and corresponding **strategies** focusing on under-enrolled specializations is needed. It should include specific actions, timelines and impact assessments, and should be circulated among faculty, researchers and students, discussed, and approved. Include: who to target, what to "sell", content, activities, connections, one-off and ongoing commitments & costs, etc. This is "non-trivial" and could take several focused, full-time weeks to prepare. Sources:
4. To incorporate **JEDI** (justice, equity, diversity, inclusion) perspectives into a marketing strategy, refer AGI's "vision and change" document (Mosher and Keen, 2021), which has sections and discussions about recruiting for a "*diverse and inclusive community*".
    - Oceanographers Johnson et al., 2016 discuss strategies for increasing diversity in ocean science workforce, thus "*cultivating future global ocean science leaders who collaborate effectively to make discoveries, achieve solutions, and develop technologies*".
    - Other sources are needed, focusing on atmospheric sciences, quantitative environmental sciences and geophysics.
5. **To heighten visibility,** make more use of **brochures, business cards, a couple of informative presentation slides, etc.**, ideally prepared by the EOAS communications team.
    - There needs to be material that students can take away whenever EOAS faculty, staff, or students engage with students or public.

    - For example, when **presenting in courses outside** EOAS, the contributor needs a handful of brochures plus a couple of slides to add to their presentation. Here is an example of a prototype flyer which needs to be improved.
6. Geophysics faculty **rarely teach in EOAS first year courses.** A colleague at Colorado School of Mines noted a similar shortcoming and agreed that that "problem" should be corrected.
7. Further **labour market research** is needed identify concrete examples of diverse career opportunities for QES graduates, with results delivered to QES faculty and articulated on "career" pages of the EOAS website.
    - This was planned for summer 2023 but the student chosen could not be hired because of immigration or work visa limitations.
    - CTLT and Career Services should be able to contribute data, although UBC does not have accounts with commercial labour market analytics data (eg. Lightcast.io).
    - There are public sources such as BC labour market statistics, and probably other Canadian sources.
    - Also, LinkedIn research would be worth while.
8. Increase the **visibility of EOAS QES degrees and research at conventions, tradeshows and meetings**.
    - This does not necessarily mean running a booth or bringing presentations. Consider sending a communications team member with a mandate to meet students, peers, industry personel, companies; to learn about hiring trends, desirable skills etc., and to hand out business cards, brochures, even EOAS / QES "merchandise".
    - These types of activities would all contribute to both visibility of EOAS and our QES programs. This would also bring regular information back to EOAS about the relevant worlds of work and academe and how they are evolving year to year.
    - A first (inexpensive) target should be Vancouver's Roundup. A communications team member needs to go with a plan of action and priorities for reporting back to the team and hence to the Department.

5.3.2 Recommendation 16. Attract BSc students when they choose their degree

There is plenty of scope here for **creativity** and energetic engagement. A few examples include:

1. Be visible in 1**st year math, physics, and chemistry**. This is already being piloted in Math; see the small TLEF grant awarded to Math Dep't.: "*Math and EOAS Collaborate to Improve Climate Education at UBC*".
2. Be more active in **Science Undergrad Society** https://sus.ubc.ca/. Many avenues of engagement. Consider including an EOAS undergraduate student from one of the clubs on the communications / PR committee to engage, report back and identify or suggest opportunities.
3. Engage with more FoS activities – eg https://science.ubc.ca/science-rendezvous-2023. Both undergraduate and graduate students could contribute.
4. Be more visible at **Meet Your Major** – May 24, 2024.
5. Explore **UBC science social media** – facebook, instagram etc., and leverage those streams. If we already have an EOAS student coordinating EOAS social media channels, perhaps they could contribute, tag, link to – or whatever – the various other UBC channels.
6. There are undoubtedly **other avenues** for engaging with incoming and existing students. This deserves additional research, prioritizing, and action-planning, ideally with priority on quantitative Earth sciences, mandated and supported by Department admin.

5.3.3 Recommendation 17. Showcase student learning and experiences

There is much that is excellent and attractive about being a student in EOAS, so the department could do more to celebrate these strengths in ways that will attract new or transfer students. Many recommendations under the "Marketing" banner are related to showcasing EOAS as an inspiring and rewarding place to earn a BSc. Some items in this list overlap with more detailed recommendations elsewhere but collecting them here hopefully emphasizes the low-cost opportunities to make the Earth sciences – and particularly the quantitative Earth sciences – more visible and attractive.

1. The communications team could do with a designated "**student liaison**" person. Their job would be to look for opportunities to showcase undergraduate life, activities and experiences, especially focusing on priorities – which would, of course, evolve (quantitative Earth sciences being a current priority).
2. Showcase ***types* of experiences** rather than specific products generated by individual students. Possibilities include:
    - Showcase clubs and social or networking events. E.g., draw on existing information from clubs and configure it for public consumption, to demonstrate "*what it's like to be in this community*". Interacting with clubs and members could part of the mandate for an EOAS communications team student liaison.
    - Examples of course work, especially projects, such poster titles from EOSC 212. Should these be updated each year? Perhaps not, but it would be easy if only the titles were listed since the list is usually circulated to faculty at end of term 1 anyway. However fetching and adding to EOAS website would need to be a designated "duty" for a web content person on the communications team.
    - What types of data do students encounter and analyze? What kinds of code do they produce? Examples could be drawn from many 3xx and 4xx ATSC, ENVR or EOSC courses. Only some examples would be needed, and annual updates would probably not be necessary.
    - Similarly, what types of problems are addressed and solved? Examples could be drawn from 3xx and 4xx assignments and labs.
    - Experiences such as field trips, interactions with community, guests visitors, seminars, etc. need to be show-cased.
3. **Existing and new web content** about students needs to be re-purposed to *inspire* rather than simply to *inform.* Details are on the "Website improvement" page.
4. **Feedback from students** could be selectively presented.
    - Selected mid-term or end-of-term survey results, including paraphrased quotes about open ended feedback
    - Comments about why/how current students chose their options have been incorporated across the EOAS website. These are titled "*A student-inspired comment*". More could usefully be obtained casually from students in a classroom or lab setting or from feedback survey data.
5. Departmental **public relations work could work more closely with students**, perhaps by building relationships with clubs. Mutually beneficial activities would be needed.
    - For example, an EOAS communications team member could attend or participate in club or departmental events (such as honors thesis presentations or course-based poster-presentation sessions) with the goal of taking a few photos and adding a corresponding item to EOAS social media and website pages.
    - Or, a club member could be invited to participate in a PR event or action by contributing a personal experience, anecdote from courses or work, or offering a suggestion for content.

6. EOAS **social media** content producers could engage more regularly with students by briefly visiting labs, field schools, or other undergraduate events and activities. The purpose would be to showcase what's fun, inspiring and worthwhile about being an EOAS student.
7. The ways undergraduates are **engaged within the EOAS Community** need showcasing. Those doing paid work or volunteering; those on committees; those contributing as teaching assistants … any instance of undergraduates contributing to the benefit of EOAS could be demonstrated in a segment about "*contributing members of the community*".
8. It is possible that an **EOAS blog site** (e.g. "*EOAS undergraduate affairs*" or "*EOAS community activity*" would be more efficient to maintain than the EOAS website, which is more cumbersome to update than the standard UBC WordPress-driven blogs.

BOX 20 - Earlier efforts to showcase undergraduate student 'products'

In 2019/20, efforts were made to showcase students "accomplishments". The idea was to cite honors theses and capstone projects by collecting details, but this focus on projects resulted in collecting only from honors theses and the environmental sciences and geological engineering capstone project courses (ENVR 400 and EOSC 445). Two problems with this notion were: (1) gathering and deliver content in a web-ready format each year was laborious, and (2) showcasing limited examples of student experiences with such detail fails to illustrate what it's like to be a BSc student in the Department.

We consulted with CTLT Web Strategy Manager Novak Rogic to discuss student content options that have been explored by other units across UBC. Discussions yielded some suggestions for ways of having students deliver work to the public domain, but when faculty have to "manage" content platforms (like blogs or wiki's) or the content itself, the process becomes unwieldy and is not sustained for long.

5.3.4 Recommendation 18. Foster partnerships emphasizing QES

1. The **Communication Director and their role & team** could be more visible to EOAS faculty, more responsive to QES faculty interests and priorities, UBC stakeholders and the public.
2. Follow up from the **SCIE 001 and Climate Math experiments** (guest speaker and climate context for first year mathematics). Will this continue? What's needed to sustain the partnership? Is the initiative visible enough to colleagues in EOAS and other departments, and UBC more generally)?
3. Also mentioned elsewhere – but **EOAS and ATSC courses should be made more accessible** to physics &/or other students.
4. Connect regularly with **other BC post-secondary schools.** BCIT, SFU, Douglas College, UNBC, UVIC, U. Van. island, Yukon U., others? Some institutions are visible at the Roundup convention held in Vancouver every January. Do this via "articulation" but also by actively connecting with physics, computing and geoscience instructing faculty.
5. Co-ordinate with **Mining Matters** in outreach efforts to students and public. This needs a little research, but a benefit is that contributing to existing initiatives is quicker/easier than instigating our own similar efforts.
6. The organization MineralsEd has a volunteer program called "**Geoscientist in the Classroom**". Example at LinkedIn here. Explore the MineralsEd website for other examples of outreach activities. Should EOAS (& GIF & MDRU, etc.) emulate or participate? Partnering with existing outreach organizations is way easier than initiating. But requires Dep't incentives.
7. **Promote more aggressively degree minors & combined options in EOAS disciplines** such as the geophysics minor. These options need to be more widely visible within FoS (especially physics) and possibly engineering.

    - This requires a person with such a mandate. They would develop creative and inspiring marketing tactics and connect personally with relevant departments and individuals.
    - **More flexibility regarding required courses** for QES degree specializations may be beneficial, for example permitting alternatives to math & computing intensive EOAS courses. Define specific goals or opportunities (such a geophysics minor for physics or astronomy students) and adjust requirements to enable – and even attract – such students.
    - "*Recruiting to Geosciences through Campus Partnerships*" by Cervato, 2021 is an example of how such marketing can be successful.
8. An "*Introduction to geophysics for geotech/mining students*" course or module (online and/or in person) may be a way of connecting with other schools & colleges, and possibly the professions. Could such a course or module be part of the engineering certificate programs?
9. Establish more concrete **connections to Canadian Earth Science community**. Could include relating PME activities & exhibits to Canadian contexts (e.g., using resources at CFES, the Canadian Federation of Earth Sciences), engaging EOAS communications team with the Canadian and BC contexts, highlighting these connections on the PME and EOAS websites via the "Outreach" main link, and likely other creative ideas.
10. Develop opportunities to **experience QES in action** as a 1-hr lesson, or 1/2-day workshop, or multiday enrichment opportunity.
    - This is not a well developed idea but was inspired by Blake et al., 2017, who describe a 4-day geoscience workforce skills training and enrichment component of the program that consists of geoscience exposure, preparation, apprenticeship, and experience.
    - The Department could leverage experiences gained running the VSP (Vancouver Summer Program), and explore whether such an experience could be delivered during jumpstart week, as part of 'Geeringup, or perhaps in some other form that involves all EOAS disciplines – perhaps a summer experience coordinated by PME as an outreach activity.
11. PME could leverage their creative strengths to **increase exposure to quantitative aspects of EOAS** and Earth sciences generally. For example, outreach activities in **meteorology and atmospheric sciences** are described in Changnon, 2004.
12. Connect with **UBC's "Science 101" initiative** to contribute an Earth Science, and perhaps even a QES, perspective. Given the target audience of this initiative, this is less about recruiting into QES and more about visibility of Earth Sciences generally among the general public. This is something PME could consider as an avenue of outreach.

5.3.5 Recommendation 19. Engage in active outreach to high schools and Vantage

Engaging with the K-12 school systems is challenging. Many ideas above are applicable or adaptable to the K-12 sector. The PME has good relations with schools, but mostly the K-7 grades. The few thoughts here are meant as starting points for discussion rather than concrete, actionable suggestions.

1. QES faculty and students need to **partner with PME** to introduce QES content accessible to school workshops, teachers and casual visitors including families.
2. **Partnering with UBC's GeeringUp** was suggested just prior to COVID. They have diverse outreach pathways and are well organized, but re-connecting will require a point-person.
3. **Engage with high schools** is an attractive idea, but we know from experience that it is challenging for several reasons.
    - Schools are badly under-resourced and activities beyond their classrooms face logistical and financial challenges.
    - Teachers are tightly constrained by provincial curriculum – they have little autonomy.

- Visiting classrooms should be feasible but requires commitment of EOAS faculty and significant organizational effort.
- Some precedent suggests that results of engaging with schools can be unexpected – even counterproductive – if not done with care. See Lyon et al., 2020.
- However – working with PME to emphasize QES aspects in all workshops should be possible if content creators can be found.
- Possible actions include:
  - Presentations at teacher professional development days;
  - connecting and engaging with high school guidance counselors;
  - direct presentations to students in their own spaces;
  - website and hard copy information materials (see "To heighten visibility" above).
  - Ask EOAS faculty with school-aged kids to connect with specific teachers. They can then ask about connecting with relevant school staff.
  - Based on experience, participating on **Parent Advisory Committees** is the best way to get to know the teachers and staff. However, even as a multi-year president of the PAC at our school, we still found it difficult to create meaningful opportunities for school students to engage with EOAS disciplines.

4. **For school kids, focus on people, not "science". Let the science emerge** from inspiring stories about who did what and how they impacted society, eco-systems, communities,, etc. Brian Fitzgerald of the Mount Washington Observatory found that middle school kids were more interested in the *people* doing the science, and *less about the science itself.* See his presentation abstract, delivered at Earth Educator's Rendezvous, 2023.
5. **Opportunities at Vantage College:** The degrees that Vantage college students can pursue after their Vantage year are summarized at Possible Specializations (Majors) After your First Year (last viewed Dec. 2023). The following notes arose from the Jan 14th, 2021 meeting with BG, FJ, PT, CH, SL.
   - Adjusting Vantage curriculum may involve rather bureaucratic and perhaps political issues. Probably not "low hanging fruit", but likely worth identifying the correct people to contact. Ask FoS Assoc Dean?
   - Recruits & families are very career-oriented. Preferred programs students want to enter are Computer Science, Cognitive Science and Statistics.
   - Science programs and core courses as of Dec 2023 are listed here. Courses are "basic" and tightly scripted – not very flexible.
   - The SCIE 113 course (First-Year Seminar in Science) may be a point of opportunity since EOAS does contribute instructing time.
   - Forestry and Land and Food Systems are expected to become options, while Arts has backed out.
   - Shandine Pete is the current (2023/24) EOAS point-person regarding Vantage.
6. **Questions re. Vantage** to resolve:
   - Can EOAS factor more prominently in the **project courses** VANT 148 & 149?
   - Who teaches the Vantage version of **SCIE 113**? Could EOAS take that on and incorporate QES, climate or other EOAS content into reading and activities?
   - Would a **Vantage-focused version of eosc110** (involving more computing, math & physics/chem) be worthwhile? Practical?
   - Are **"guests" from EOAS in Vantage courses** practical? Worth while? Just prior to the COVID pandemic, this was considered by Brett Gilley (teaching at Vantage) and Christian Schoof (glaciology and climate modeling). The notion needs re-booting.

5.3.6 Recommendation 20. Alumni engagement

Alumni engagement for EOAS (particularly the QES graduates) needs rethinking. This is a "bigger picture" task for the department.

1. **Can the department engage with alumni without going through UBC alumni "system"?** For EOAS that has been through the Faculty of Science Assistant Dean, Development and Alumni Engagement (Allan Berezny as of November 2023) . See also https://science.ubc.ca/alumni. However, this has proven slow and unreliable.
2. Explore **creative ideas from the literature,** for example Ashline, George, 2017, who developed a network to provide students with information and inspiration, and to support lifelong learning through the development of collaborative relationships between alumni and faculty and students.
3. Regarding alumni profiles: The **Alumni survey** used to obtain professional profiles to showcase (Sept 2022) yielded only one out of 14 contacted (with FoS alumni support).
    1. A template for a professional profile pages was made for F. Jones.
    2. There is a more general version of this survey targeting others. It was intended to be sent to BCGS and KEGS executives. It could still be used but should be shortened.
    3. OR – individuals could be contacted for a 1/2 hr interview using 2-3 of those questions. See the Central Washington University example for precedent and interview questions.
4. **Industry contacts** were gathered (36 to date) in a spreadsheet: (industry, gov, academic) = (21, 6, 5), and (atsc, geop, envr, geol, ocgy) = (11, 14, 1, 1, 2). Followup by adding to this using a LinkedIn search, then treat as a source for alumni (and other) contacts for showcasing. (Spreadsheet on NextCloud: *...\QUEST\marketing\showcase\industry contacts221107.xlsx*)
5. Gather **public-domain alumni information** based on LinkedIn data (eg here). Whether this would be ethical needs discussion. It could result in content more like a table or list rather than full profiles. In fact, it may be more appropriate than full-on profiles of individuals, and certainly more doable since contacting individuals would not be needed.
6. **Showcase pathways into geoscience occupations** using an efficient model developed at Boise State University. The assignment details and results were presented at the EER 2023 workshop by A. Egger, and are summarized on our activities for exploring careers page. It should be possible to implement this procedure without UBC's permission. It only requires a 20-30 phone or zoom call, with 3-4 questions to standardize the information gathered.

5.4 Website improvements

5.4.1 Recommendation 21. Enhance EOAS website content for QES recruiting

This section is about **public facing** content, not information for **current students.** Student advising, career preparation, program requirements, etc. should be provided on a platform that is easy to adjust annually. A Canvas-based advising resource would serve that need; see the students support page for this and other related recommendations.

Web content can be prepared for delivery at the EOAS website, but posting and maintenance requires computing staff or web-team support. Content might more sustainably be prepared as an EOAS blog post on one of UBC's blogging platforms. Maintenance can be assigned to anyone with a CWL and the WordPress platform is flexible, easy to learn, and permanent at UBC. For example, the PME website is hosted this way.

1. **Each web-content suggestion is not "difficult" but** needs to be on an active task-list for the website and communications teams.

- Oversight (communications director?) is needed to approve and check off items from the list.
   - Content creation is an ideal activity (if well supervised) for volunteer or paid students with the communications and website teams.
2. Existing and new web content about students needs to be **re-purposed to *inspire* rather than simply to *inform***.
   - In other words, with a bit of creativity – and this shift in perspective or goals – content for and about undergraduates could be reconfigured to be more appealing to prospective students.
   - This means re-thinking the Undergraduate segment of the website, especially these three sections: "Why EOAS?", "Student Achievements" and "Student Life and Events".
   - Adjusting content from "*present the information*" to "*inspire and make the viewer wish they were here*" does not come easily for most scientists because their communication skills were developed to convey information in efficient, didactic, "presentation" styles.
   - Therefore, consider hiring a student from a marketing program or someone with advertising experience. Perhaps consult with UBC's media relations team.
3. **Reintroduce information about EOAS courses**. With no details other than the necessarily curt calendar descriptions, students can neither recognize the **relevance and interest** of these courses not anticipate what they are "in for".

BOX 21 - Website background, recommendations & discussion.

- ***Background**:* The new EOAS website (to go live early Fall 2023) will no longer have details about every EOAS course. This decision was based on the difficulty of convincing instructors to take responsibility for keeping these pages up to date. Service courses will have attractive descriptions, but the course details database will no longer exist. However, dropping this opportunity for visibility because instructors won't keep content current is the wrong action. Instead of dropping, an alternative means of building and maintaining needs to be developed that does not rely on instructors.
- ***Recommendation**:* reintroduce course description information on the EOAS website to help students set expectations and characterize the course's place within degree program curricula. A very simple course description template is needed, perhaps just one description-editing field and one attractive or relevant image. Course Learning Objectives should ideally be included but consistency would be needed for all EOAS courses. (Perhaps requiring these for website use would in fact encourage them to be generated.) UBC information can either be pulled from the Calendar or simply point to the calendar (which uses permanent URLs).
- ***Discussion***: If the course details database is simplified, it should not be too much to ask for annual revisions of this information. It could be as simple as current instructor and course's learning outcomes (CLOs). Surely faculty could be expected to carry out a quick review and update, perhaps in May prior to students registering for courses in the upcoming year? In fact (and ideally) EOAS course webpages could become complete & consistent syllabi for each course, adhering to the minimum UBC-wide recommendations.

4. **Make scholarships & awards from outside UBC more visible**
   - Augment the scholarships page to summarize opportunities beyond UBC.
   - Existing students need to be able to find this in the Canvas advising resource, but prospective students need to see there is financial support they can apply for.
   - Example: the **handout** with Opportunities for geophysicists (fall 2022) was provided to geophysics students in fall 2022, but an augmented version is needed including opportunities for ocgy, atsc and perhaps envr.

5. Build a showcase page about **courses involving physics & computing** like the one for climate related courses. Leverage lists at the courses-by-topic page.
   - QES program "navigator" information could also be made available as a brochure.
   - Other programs could benefit from navigator pages once there is an effective template.
6. In the EOAS website's "Degrees" section add a **Combined Options** section at the same level as the seven specializations now visible. Include https://science.ubc.ca/students/programs/integrated-sciences, Double major, Minor in … , Honours, Majors, Combined Honours.
7. Augment and modernize the **QES & geoscience careers and opportunities page**. The existing "Career Paths" page is great, but it could emphasize the diversity, importance and rewards of career options (traditional and otherwise) available to students with QES degrees.

BOX 22 - QES showcase details.

- **Where** to put (or point to) this content? (a) On the "Why EOAS" page - but maybe rename this as "Why study Earth sciences in EOAS" (b) On the "Career Paths" page, perhaps with sub-pages if needed.
- Content should be **relevant for several years** to come.
- It is more important to be **attractive and inspiring** than "complete". No one (least of all students) will read long segments of text.
- **Public are** more interested in people (individuals) and "*how it affects me*" stories rather than "pure" science or engineering.
- **Prospective students** are also more interested in "*me*", "*people*" and "*altruism*" than field work or discipline-specific details. **Parents** and most students are also keenly interested in the potential of a career for wealth & stability.
  - Reasons **altruism is more important to students** than other factors are discussed in Carter et.al., 2021.
  - Examples of how **quantitative Earth science serves humanity** can be found in "*Mapping geophysics to the UN sustainable development goals*", Capello et al., 2021.
- **Pointers to third party content:** Focus on "*Impacts*", "*Opportunities*" and "*Rewards*". Highlight the variety of professionals, especially EOAS graduates.
  - Organizations with **current workforce information**; see the QES organizations page.
  - Showcase a report for **Geoscientists without Borders,** about the EOAS / industry team's project to help improve Water Security in Myanmar. See also Geoscientists without borarders home page.
  - Online seminars such as (a) "Groundwater Exploration in Response to Humanitarian Crises" at AGI; (b) SEG has seminars but for members only. eg. "Taking the Power of Exploration Geophysics from the Oil Patch to Help Solve the World's Grand Challenges", (c) recorded EOAS seminars, (d) find others.
  - Include pointers to existing people and articles from https://www.eoas.ubc.ca/news-events/news.
  - Find more like: "Atmospheric scientist", in The Science Teacher; Vol. 86, Iss. 7, (Mar 2019): 62-63. Explore the same journal for more of the same.
  - Find other public spot-lighting of geoscience, atmospherics, physical oceanography or quantitative applications in environmental science in action.
- Consider alternate forms for delivering content that was prepared for the web. Maybe flyers, downloadable PDFs, handouts, use during lessons, labs or assignments, & others
- From **BC & Canadian geophysical** (BCGS, CSEG, KEGS, and others) community, ask / learn about careers for greening economies, scholarships, internships, showcase occupations.
- Gain **inspiration** for content from physics, math, computing Department career description pages, for example, UBC's PHAS page.

8. **Improve** the FoS page "What can I do with a BSc in Geophysics?". That page is OK but does not answer the title's question. Instead, it answers – "*what is the intellectual scope of geophysics researchers?*". Career options are listed *generally,* not in terms of **contributions to society**.
    - EOAS needs a **similar page** but one focused on how people with degrees in geophysics, atmospheric science or oceanography are contributing to society. It needs to refer to alumni and others.
9. The **alumni "showcase" page** needs modernizing and maintaining regularly. It would not be onerous to add one or two entries each year, especially if there was an efficient repeatable procedure. See recommendations involving alumni elsewhere.

6 DATA SETS, REPORTS & FACULTY DISCUSSIONS

This page contains pointers to (1) data collected and corresponding results, and (2) summarized faculty discussions.

6.1 DATA, INTERVIEWS & RESULTS

Data sets gathered, interviews conducted and interpretations of results.

No.	item	type	Description	Date
19	**Desirable capabilities**	Full Report	Based on interviews, discussions, surveys, workshops and literature. Summary.	Nov2023
18	**Paired interviews**	Data Interview results	Interviews of 19 QES faculty in pairs about quantitative learning in EOAS.	Mar2023
17	**Learning tasks encountered by QES students**	Data survey results	Compiled data from a Qualtrics survey about learning tasks that students experience in EOAS. **56 respondents** as as of March 2023.	Sep2022, Mar2023
16	**Interviews: Fundamentals vs. career prep**	Data Interview results	Interpreting interviews of 20 EOAS faculty regarding fundamentals vs. career preparation.	Sep2022
15	**Computing in EOAS**	Data Raw data	Spreadsheet summarizing how computing is used in each EOAS course. Updates requested by M. Jellinek in March '23. Comments in sec'n 4 of the "Current course content" page.	Aug2022 Mar2023
14	**Assessing Syllabi and CLOs**	Data survey results	An assessment of 27 course syllabi and Course Learning Outcomes for their content and compliance with UBC expectations. Data file is "*Syllabi-characteristics.xlsx*".	Aug2022
13	**QES course content**	Data Results report	Summarized, using information requested from instructors (2020-2021). Data file "*QES-coursematrix-220216.xlsx*"	Feb2022
12	**EOAS Enrolments**	Data Plots	Enrolments in EOAS BSc degree prgrams, 2005-2020.	Apr2021
11	**EOAS graduate student survey**	Data Results	~50% response rate (N=74), about timelines, satisfaction, COVID, finance, with quantitative & open questions.	Sep2020
10	**EOAS Program Learning outcomes**	Data Table	Table of official program learning objectives for QES degree programs, summarized for comparison.	Sep2020

9	**EOSC 1xx demographics**	Data Results	**EOAS first year course enrolment** Demographics to inform discussions about a new EOS 1xx course for quantitative students. N = 6059 students.	Sep2020
8	**Student Experiences**	Data Summary	"**Student Experiences** in EOAS Specializations"; report by A. Jolley. This doc is a summary. The complete 46-pg survey report is available here.	Mar2020
7	**Peer institutions**	Data Report	Discussions with **peers at 7 peer institutions**; summarized in note form.	Jan2020
6	**Peer institution degrees**	Notes Report	Summary of 6 institutions produced by CTLT (C. Hunter) in early 2020.	Jan2020
5	**QES skills reported by faculty**	Data Results	QES skills from survey responses at the EOAS Dep't retreat, May spring 2019. Also as a matrix, although perhaps not quite so informative.	May2019
4	**Geophysics student feedback**	Data Survey results	**Geophysics student feedback** survey; short report by A. Jolley, 2018.	Dec2018
3	**EOAS Alumni survey,** 2015: data	Data Survey results	**Alumni** survey results from 2015, reported by Grad student who analyzed results.	Sep2015
2	**EOAS Alumni survey,** 2015: open comments	Data image	Open qn answered by 54% of 194 respondents (alumni): "Students need more of …" in spreadsheet "*alumnidata-2015.xlsx*".	Sep2015
1	**Geoscience hiring**, 2010	Data Report	Industry insights: EOS Survey of Hiring Practices in Geoscience Industries, 2010. At UBC Library's CirCLE repository.	Jun2010

6.2 FACULTY DISCUSSIONS

No.	item	type	Description	Date
7	**Progress report**	Report PDF	Progress re port to the Dep't Head, F. Jones,	Aug2022
6	**Progress report**	Report PDF	QuEST report to the Department, C. Schoof.	April2021
5	**EOAS Strategic Plan**	Report PDF	Strategic plan, Dec 2020, P. Tortell	Dec2020
3	**QES: desired content & methods**	Discussion Page	Early thoughts about concepts & tools synthesized from deliberations during summer 2020 and earlier.	Sep2020
4	**Rejuvenating QES; priorities**	Discussion Page	Summary of discussions between May and Sept 2020 about the QuEST project's scope and priorities.	Sep2020
2	**A new EOSC 1xx QES course**	Discussion PDF	Summary of a written exchange discussing pros, cons & options for a new 1st year course targeting quantitative first year students.	Sep2020
1	**Micro-credentials**	Notes notes only	Notes based on current examples from two EOAS faculty.	Aug2019

7 References

7.1 Characteristics of this reference list

There are 86 references cited in QuEST documentation, with academic subject coverage and educational contexts summarized as follows:

Some **additional web resources** are included below the list, including information sources provided by UBC. A few further references used for a poster presented at AGU, 2021, are also included.

Presentations about QuEST work within UBC and at external conferences are listed at the end.

QuEST reference list categories

Academic subject area		Educational context	
Article focus areas	Num. refs.	Article focus areas	Num. refs.
geosciences	26	pedagogy	32
none or generic	21	career preparation	32
math	8	other	13
Data or computer sci.	8	curriculum	11
physics or chemistry	7	Faculty & TA Dev	9
geophysics	7	marketing	4
oceanography or biol.	6	JEDI	4
engineering	4		
atmospheric sci.	2		
medical	2		

7.2 The reference list

Note this reference set is gathered as a Zotero collection owned by F. Jones but visible to public at https://www.zotero.org/groups/4680105/qes_curriculum/library.

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6. **EER 2023** (Earth Educator's Rendezvous workshop/meeting): a **3-morning workshop** "How is your Program Helping Students Prepare for the Jobs they Want?". Their program page includes links to workshop materials and outcomes, plus several excellent career-preparation related references and resources listed at the end of that page.
7. **EER 2023**: a **2-morning workshop** "Teaching Quantitative Reasoning with Real Data – The EDDIE Way!". Their program page includes links to workshop materials and outcomes.
8. **EER 2023**: A **2.5 hr session** "Creating an Online Learning Environment about Geoscience Careers and Licensure", Craig Nichole, UBC-OK.

7.4 UBC SOURCES

- **Executive summary** for the EOAS department's strategic plan, *EOAS 2021: A Vision for Integrated Earth Science*, P. Tortell, Dec 7, 2021.
- **Course enrollments and demographics** (gender, indigenous, etc) are at UBC's PAIR "enrollments" data site.
- **Students' career and experiences** resources website.
- **Program Renewal:** what is it? A process of aligning the courses and learning activities in a program (such as a major, minor, specialization, diploma, or certificate), so that students are adequately supported in achieving the program's overarching learning goals.
  - **Approaches to program renewal** page.
  - **Curriculum and program renewal**; article in CTLT's newsletter "edubytes" Nov. 2021.
  - **UBC's "program renewal" advice**.
  - **Older UBC source**: curriculum renewal workshop, 2011.
- **UBC curriculum mapping tool**: MAP.
- **Fundamentals vs career preparation**:
  - A report prepared for us by K. Rawes.
  - the current (2023) "Career in Courses" resource.

7.5 FROM AGU POSTER, DEC. 2021

Seventeen references were cited by, *Jones, F., C., Schoof, P. Austin, T. Invanochko: "Reinvigorating Computational & Quantitative undergraduate Curricula for the Earth, Ocean, Atmospheric, Environmental and Planetary Sciences at UBC", **American Geophysical Union** (AGU) poster (link may not be permanently available to the public). See also a single HTML page version.*

BOX – 22 Sources NOT included above; most relate to teaching computing.

- **Tenenberg, Josh, and Sally Fincher**. "Opening the Door of the Computer Science Classroom: The *Disciplinary Commons*." *ACM SIGCSE Bulletin* 39, no. 1 (**March 2007**): 514–18. https://doi.org/10.1145/1227504.1227484.
- **Sangwin, Christopher J., and Claire O'Toole**. "Computer Programming in the UK Undergraduate Mathematics Curriculum." *International Journal of Mathematical Education in Science and Technology* 48, no. 8 (**November 2017**): 1133–52. https://doi.org/10.1080/0020739X.2017.1315186.
- **Margulieux, Lauren, Tuba Ayer Ketenci, and Adrienne Decker**. "Review of Measurements Used in Computing Education Research and Suggestions for Increasing Standardization." *Computer Science Education* 29, no. 1 (**January 2019**): 49–78. https://doi.org/10.1080/08993408.2018.1562145.
- **Dorn, Brian, and Allison Elliott Tew.** "Empirical Validation and Application of the Computing Attitudes Survey." *Computer Science Education* 25, no. 1 (**January 2015**): 1–36. https://doi.org/10.1080/08993408.2015.1014142.
- **Green, David.** "Pair Programming: Benefits, Tips & Advice for Making It Work — SitePoint," January 21, 2020. https://www.sitepoint.com/pair-programming-guide/.
- **Alammary, Ali.** "Blended Learning Models for Introductory Programming Courses: A Systematic Review." *PLoS ONE* 14, no. 9 (**January 2019**): e0221765. https://doi.org/10.1371/journal.pone.0221765.

- **Weiss, Charles J.** "A Creative Commons Textbook for Teaching Scientific Computing to Chemistry Students with Python and Jupyter Notebooks." *Journal of Chemical Education* 98, no. 2 (**February 2021**): 489–94. https://doi.org/10.1021/acs.jchemed.0c01071.
- **Manzoor, Hamza, Amit Naik, Clifford A. Shaffer, Chris North, and Stephen H. Edwards.** "Auto-Grading Jupyter Notebooks." In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, 1139–44. SIGCSE '20. Portland, OR, USA: Association for Computing Machinery, **2020**. https://doi.org/10.1145/3328778.3366947.
- **Furman, T., and M. Modwin.** "Higher Education During the Pandemic: Truths and Takeaways." Eos. Accessed **July 2021**. https://eos.org/opinions/higher-education-during-the-pandemic-truths-and-takeaways.

7.6 Presentations & reports about QuEST work

1. **QuEST project overview,** EOAS Dep't retreat, spring 2023.
2. **Progress report** to the Dep't Head, F. Jones, Aug. 2022 (PDF).
3. **UBC TLEF Showcase** – OCESE project poster, 2022
4. **UBC Science Education Openhouse** – QuEST project poster, spring 2022
5. **AGU poster** (QuEST **and** OCESE), Fall 2021
6. **Progress report** to the Dep't, C. Schoof, April 2021 (2 page PDF).
7. **UBC TLEF Showcase** – OCESE project poster, spring 2021.
8. **OCESE project** presentations (related, but not explicitly QuEST project outcomes).

8 Appendices

On the following pages …

END

APPENDICES – QuEST project report

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Appendices are summarized in this table. Every appendix is provided in detail in sections below. The links point to online pages at the project's documentation website.

No.	Appendix	Description
1	Canvas-based recommendations	**Blog pg.** Discusses a Canvas-based resource for advising, career preparation & community-building. A prototype has been built and reviewed by some EOAS faculty (October 2023) but has yet to be considered seriously by the Department.
2	QES course dependencies	**Blog pg.** Prerequisite and co-requisite dependencies among EOAS quantitative courses only (ATSC, EOSC, ENVR) are discussed and a few thoughts presented.
3	Priorities, summer 2020	**Blog pg.** Summary of discussions among some EOAS faculty between May and Sept 2020 about the QuEST project's scope and priorities.
4	Early concepts, tools & programs	**Blog pg.** Synthesized notes from deliberations about objectives, concepts and courses of the quantitative Earth sciences generally, based on discussions during summer 2020 and at Dep't retreats of 2019 and 2020.
5	QES organizations	**Blog pg.** A page with pointers and references that showcase career options in geosciences in general and the quantitative geosciences in particular.
6	GROW Site Map	**Blog pg.** The Geoscience Resources on Opportunities in the Workforce (GROW) resource was prepared in 2022 with funding from NSF. It is extensive and inspiring, hence the outline presented here as a potentially useful resource for students.
7	Activities for exploring career options	**Blog pg.** Two examples from two institutions of initiatives that have students discover and think about geoscience career options.
8	AI and learning	**Blog pg.** A few preliminary thoughts about use and abuse of AI as part of learning and teaching.
9	For Instructors	**Blog pg.** Key resources and guidelines related to undergraduate teaching and student support offered to instructors at start of term in late August, 2023.
10	Profile – FJ	**Blog pg.** An example of one way to profile alumni or other professionals.
11	EGBC registr'n; Courses checklist	**PDF**; EOAS courses mapped onto the EGBC "self-check" requirements. (Aug. 2023)
12	Advising tool for geophysics	**PDF spreadsheet:** Geophysics course list with columns to map curriculum against Faculty & EGBC requirements. (Aug. 2023)
13	Geophysics Scholarships	**PDF;** table of scholarships for geophysics students. (Preliminary, to be augmented, and other disciplines added). (Nov 2022)
14	EGBC registr'n; notes	**PDF;** notes on Geoscience Knowledge and Experiences (GKE) requirements for professional registration in Canada. (Aug 2022)
15	Capstone experiences; Advice Report	**PDF**; a report summarizing the types, roles, benefits and keys to success by C. Hunter, CTLT Includes 18 references. (Aug 2022)
16	Math/Geoph career preparation Notes.	**PDF;** Annotated bibliography about career Learning in Geophysics and Math Courses; an annotated bibliography prepared by **K. Rawes** (UBC's Career Centre); augmented by F. Jones.
17	Interactive curriculum map web site	**WebSite;** Interactive graphic maps of QES course dependencies for 2nd, 3rd and 4th year courses, including reference to courses outside EOAS (several coupled web pages).
18	Curriculum map observations Report	**PDF;** Observations and comments about QES course dependencies. (Nov. 2021)
19	Pre-requisite competencies webpage	**WebSite;** Expected capabilities by subject (not course) for each EOAS quantitative courses. Data file "*AllPrereqs.xlsx*".

See also the Data Sets and Reports and Tools and Resources pages.

8.1 CANVAS-BASED RESOURCE FOR ADVISING, CAREER PREPARATION & COMMUNITY-BUILDING

What and why

In **UBC-Okanagan's Dep't of EEGS,** a Canvas "course" is regularly used by all advisors and students pursuing EEGS degrees. It provides information about their programs, advising, career preparation and departmental activities. It includes short videos with information from advisors or interviews with alumni and experts such as Head of Registration for EGBC (professional engineers and geoscientists in BC). It was generated and is maintained by Prof. Craig Nichole at UBC-OK. A version of this resource has been prepared for EOAS for consideration. See the Canvas site itself (CWL required)

Delivering resources in this manner has several benefits:

1. All students can find information when they choose rather than having to book appointments with advisors. Meeting with advisors should still be expected, but these can focus on individual needs if the basic information is available at a familiar location.
2. A Canvas site is not public but is automatically accessible to all students.
3. Videos and documents provide succinct information that would normally have to be presented frequently and sometimes repeatedly. This saves time for advisers and students.
4. Information from people outside the Department is efficiently presented, such as a video explanation of how professional registration works in BC.
5. Links to external resources, such as scientific and professional organizations and their information can be provided so students can be directed efficiently as needed.
6. Canvas announcements can be used for regular or one-off communications, and all students will 'automatically' be made aware of these information updates.
7. Maintaining content is in a format that is both online and easily accomplished since all instructors are familiar with the Canvas interface. Similarly, files (eg PDFs) are easily delivered to a Canvas site.
8. Communication with all students, a subset, or individuals is easily accomplished without having to go through the email lists that are accessible only to Dep't staff or advisors. This should help increase the immediacy, relevance and effectiveness of faculty – student relationships, thus increasing everyone's sense of community within EOAS.
9. Materials that may be of interest in more than one course can be made available and maintained. For example, this Canvas site could be a source or starting point for learning activities related to career preparation, exposure to scientific organizations, access to databases, etc.. This approach to delivering such content will make it more efficient for instructors to incorporate corresponding activities into their courses.
10. Departmental activities such as seminars, awards events, networking opportunities, etc. can be announced, with scheduled event-announcements prepared in advance for timed release.
11. Key students such as club presidents could be given limited access to generate their own announcements or materials.

A prototype called "EOAS Student Info 2023/24" tailored for EOAS is being prepared (August 2023) by modifying a copy of the EEGS resource, and incorporating insights gained in the geoscience careers workshop that FJ and SBS attended at EER 2023. Manuel Dias (SkyLight/CTLT) has initiated this Canvas site so that EOAS undergraduates can enroll themselves as students using this URL:

https://canvas.ubc.ca/enroll/KLHK6T and their CWL. Any (or all) instructors can be give access as needed, to update or add content.

Feedback from EOAS faculty:

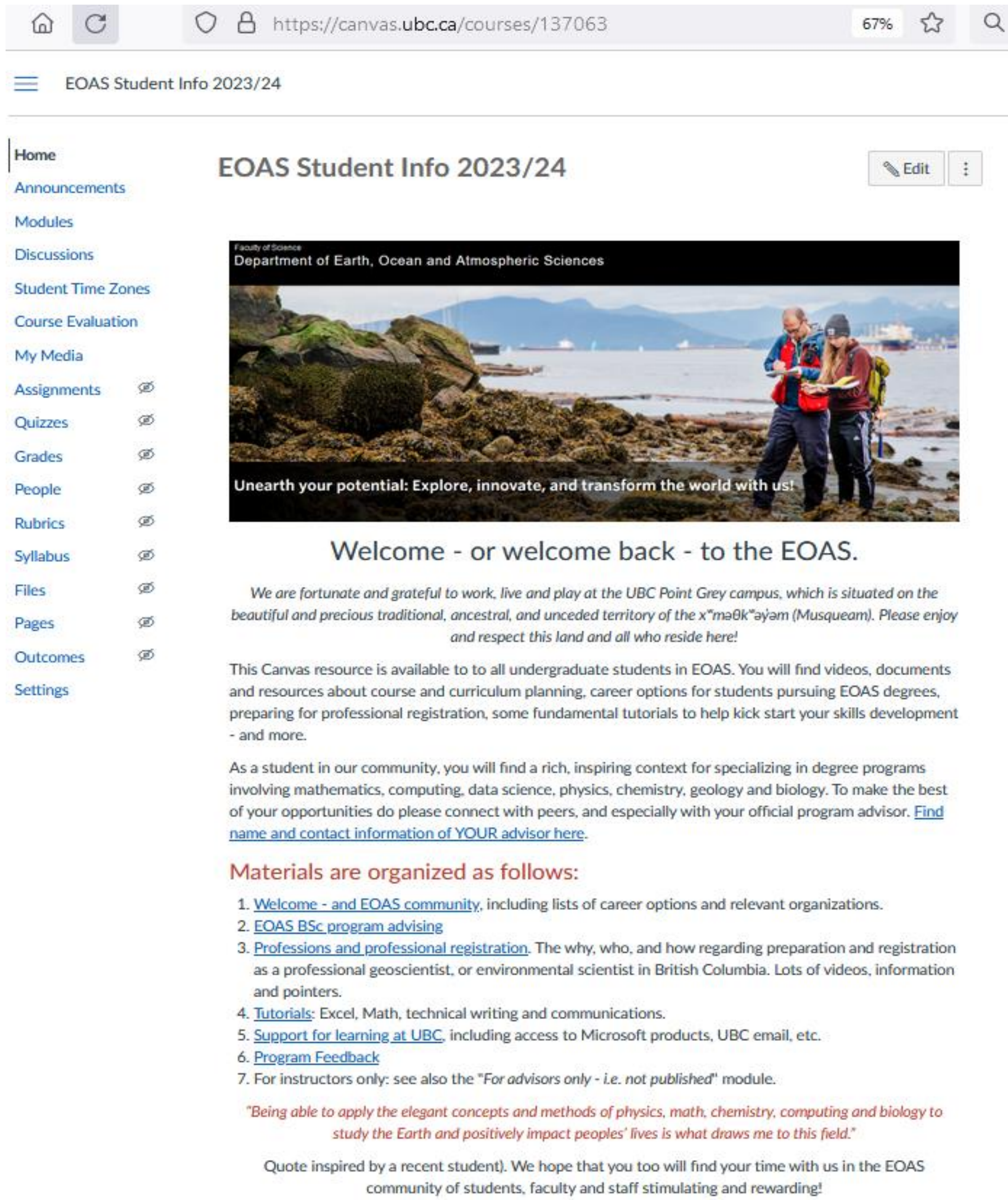
- One professor involved in advising EOAS students agrees such a facility has potential.
- Quotes from another EOAS faculty reviewer:
- I like the student info canvas site. Would love to sit and go through some of the things with you if you have some time soon.
- I think this would be a great place for students to find things, but only if it is managed and kept up to date. The problem with all of these things is that they get old fast.
- A cool addition could be Graduate testimonials – maybe some short video clips from recent graduates on what they are doing in their careers. Possibly a few from not-so recent graduates too.
- I flip between liking and hating the modules in Canvas – its so bland with lots of things to click on. Perhaps each Module could be a page – where you can embed images and video clips? It might make it more engaging for students? Anyway – just a few thoughts for now. I like it, and think it will be a great resource.

1.1.1 Suggested content for EOAS – to be discussed

A balance will be needed between public facing content which should be on the main EOAS website (see the marketing ideas page) and content that is more appropriate for students already enrolled in EOAS programs that can be provided on this Canvas "course" site.

Suggested content is outlined in a planning document on the Canvas site. If the Canvas resource is not considered viable in EOAS, the content produced can be distributed partly onto the EOAS website, and partly into this QuEST document.

As of Aug. 2023, the home page, with an outline of content, looks like this:



https://canvas.ubc.ca/courses/137063 67%

EOAS Student Info 2023/24

Home
Announcements
Modules
Discussions
Student Time Zones
Course Evaluation
My Media
Assignments
Quizzes
Grades
People
Rubrics
Syllabus
Files
Pages
Outcomes
Settings

EOAS Student Info 2023/24

Edit

Faculty of Science
Department of Earth, Ocean and Atmospheric Sciences

Unearth your potential: Explore, innovate, and transform the world with us!

Welcome - or welcome back - to the EOAS.

We are fortunate and grateful to work, live and play at the UBC Point Grey campus, which is situated on the beautiful and precious traditional, ancestral, and unceded territory of the xʷməθkʷəy̓əm (Musqueam). Please enjoy and respect this land and all who reside here!

This Canvas resource is available to to all undergraduate students in EOAS. You will find videos, documents and resources about course and curriculum planning, career options for students pursuing EOAS degrees, preparing for professional registration, some fundamental tutorials to help kick start your skills development - and more.

As a student in our community, you will find a rich, inspiring context for specializing in degree programs involving mathematics, computing, data science, physics, chemistry, geology and biology. To make the best of your opportunities do please connect with peers, and especially with your official program advisor. Find name and contact information of YOUR advisor here.

Materials are organized as follows:

1. Welcome - and EOAS community, including lists of career options and relevant organizations.
2. EOAS BSc program advising
3. Professions and professional registration. The why, who, and how regarding preparation and registration as a professional geoscientist, or environmental scientist in British Columbia. Lots of videos, information and pointers.
4. Tutorials: Excel, Math, technical writing and communications.
5. Support for learning at UBC, including access to Microsoft products, UBC email, etc.
6. Program Feedback
7. For instructors only: see also the "*For advisors only - i.e. not published*" module.

"Being able to apply the elegant concepts and methods of physics, math, chemistry, computing and biology to study the Earth and positively impact peoples' lives is what draws me to this field."

Quote inspired by a recent student). We hope that you too will find your time with us in the EOAS community of students, faculty and staff stimulating and rewarding!

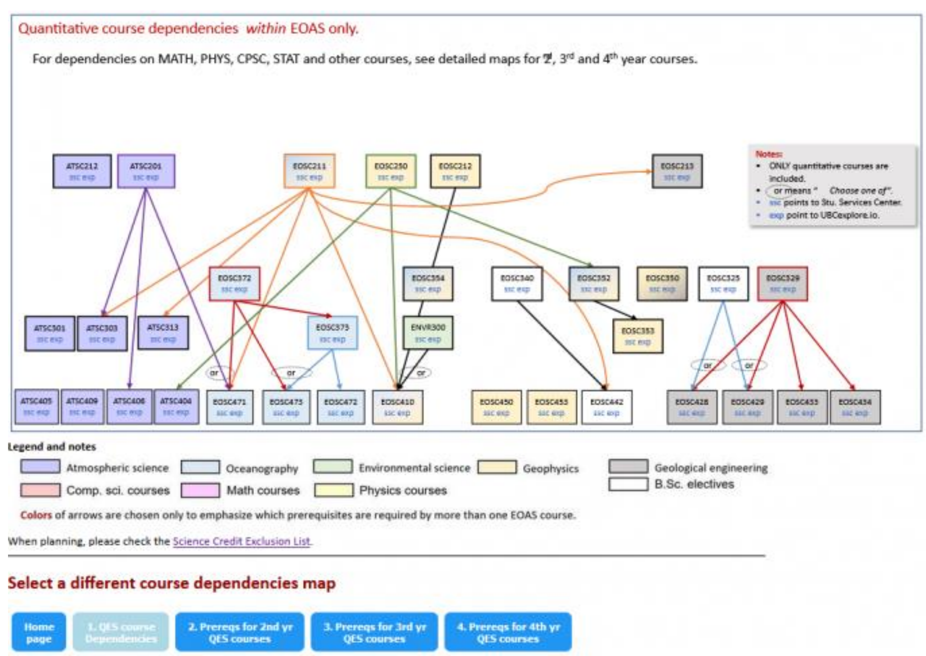
BOX A1 - The original EEGS facility's 19 modules

1. Welcome to the Earth, Environmental and Geographic Sciences Department
    1. new PDF each year
2. Department Talks
    1. pointers to department seminars
    2. reference to video presentations by EGBC, BCIA and ECO Canada
3. Earth and Environmental Sciences Major: degree details and pointers to UBC info. + 3 videos introducing the advising for this program.
4. Freshwater Science Major: degree details and pointers to UBC info.
5. Geospatial Information Science Minor: degree details and pointers to UBC info.

6. EESC and FWSC Honours Thesis: info. on requirements and expectations.
7. General Information on Different Careers in Earth and Environmental Science
    1. pointers to 7 geoscience career websites in Canada and US.
8. Overview of Professional Registration
    1. Outline of how the process works
    2. videos about the professions
9. Professional Registration: Professional Geoscientist (P.Geo) with Engineers and Geoscientists BC
    1. 16 resources including advising, course checklists, BC and Canadian contexts, & videos.
    2. The "Curriculum maps" (PDF) are particularly detailed - maybe more than needed?
    3. ***ToDo: These should be reviewed to identify what's relevant for EOAS.*
    4. *?? Qn: are all those pointers to (eg) Geoscientists Canada, etc. needed? Maybe they belong in a reference list instead as items in the module?*
10. Professional Registration: Professional Agrologist (P. Ag.) with the BC Institute of Agrologists
    1. videos about agrology, BCIA and for advising
    2. pointers to approved courses & academic worksheets
11. Registration with Eco Canada (www.eco.ca)
    1. videos and pointers
12. Information on Signing up for Microsoft OneDrive (one pointer)
13. Resources to Help With Online Teaching and Learning (several pointers)
14. Excel Tutorial: pointer to xlsx 10-sheet spreadsheet with "very" detailed how-to starting from scratch, and working towards charts, including dual axes and trend lines.
15. Mathematics for Earth and Environmental Sciences Tutorials: Pointer to SERC resource "[The math you need when you need it]".
16. Technical Writing and Communications Tutorials: pointers to 11 videos ([EEGS Youtube channel]).
17. Academic Integrity: pointers to institution stuff
18. Program Feedback Survey: survey to offer feedback to the department.
19. Geoscience Licensure in the US: empty at 230725.

8.2 EOAS QES COURSE DEPENDENCIES

Prerequisite and co-requisite dependencies among EOAS quantitative courses (ATSC, EOSC, ENVR) are mapped in the interactive pages linked here. Information available is explained on that home page. Briefly, the course name, outline, credits, discipline area, and links to UBC calendar as well as the https://ubcexplorer.io site which links dependent courses to determine both pre-requisits and courses dependent upon any course at UBC.



Click the image to explore this curriculum map in a new window.

2.1 A few observations based on reviewing these maps

1. General observations
    a. Is it true that some prerequisite abilities can be NOT specified if they are either implied by course sequencing, or if the prerequisite is part of a degree's requirements?
    b. "Corequisites" are only mentioned twice, once for EOSC250 and once for ATSC404.
    c. After collapsing "one-of" lists, all courses have 3 or fewer prerequisites EXCEPT eosc410 and 471.
2. EOSC 2xx:
    a. Only four EOAS courses taken by BSc EOAS students require EOSC211: ATSC303 and 313, EOSC 410, 471. EOSC 213 is engineers only, 442 is not taken by EOAS students, and several CPSC, PHYS and ASTR courses can "depend" on EOSC 211.
    b. EOSC213 is not *required* by any other course in EOAS, and only as "one of" 3, for CIVL417. See "dependent courses" near end of this page.
    c. For any course requiring EOSC211, should DSCI100 count too? Currently, ATSC313 is the only EOAS course with DSCI100 as a "one-of" prerequisite.
3. EOSC 3xx
    a. At 3rd year level, only ATSC303 and 313 require any computing. Not even EOSC211 or DSCI100 are required.
    b. Why is EOSC354 not prerequisite for EOSC353? (More on eosc353 in Questions below.)
4. EOSC 4xx
    a. Two ATSC and two geophysics 4xx courses require no EOAS prerequisites. This possibly helps attract students from other disciplines, but means there is no certainty about student capabilities coming into the course.
    b. EOSC410 seems quite restrictive to undergrads (and taken by only ~4-8). See Questions below.
    c. The "any programming language" for ATSC405, 409 is vague. Is that OK?
    d. Do EOSC 45x really need no computing, or are capabilities assumed owing to 4th yr status in science?

2.2 Update dependencies

Reasons for reviewing dependencies include clarifying what is actually needed going forward (eg. computing skills), and improving access for non-EOAS students, eg by adding SCIE001 or alternative MATH or PHYS courses, where possible.

1. Consider having 4xx "specialist" courses include at least some "either or" prerequisites from EOAS, eg ATSC405, 406 and EOSC450, 453.
2. Could ATSC303 have more options for computing prereqs? Currently EOSC211 alone is required.
3. EOSC354:
    a. Could Calc1 be swapped out in favour of EOSC211 or equivalent? EOSC211 requires Calc1.
    b. Augment physics requirements by adding PHYS153 & PHYS106 to the either/or.
4. Add SCIE001 to any requirements for Calc1 (three 3rd yr courses) or Physics101 (eg EOSC250).
5. ATSC313: augment physics requirement by allowing PHYS153 & 106?
6. ATSC405: augment Diff Eqns requirement by allowing MATH255 or 256?
7. ATSC404: augment Applied Des requirement by allowing MATH257?
8. EOSC410:
    a. augment stats requirement to include STAT201 or 251?
    b. augment cmpsc requirement to include five courses in "pink" box?

9. EOSC471: augment requirement to include five courses in “pink” box?

2.3 Questions

1. EOSC211
    a. Student feedback from Dawson club members, reported March 11, 2022: “*significant proportion of the class gets lost very soon and never really gets it. Peers attempt to support but often without seeing any breakthrough in understanding”*. Details not conveyed, but dissatisfaction seems fairly widespread.
    b. Geophysics has included DSCI 100 in required courses. Other programs have not. This will give geophysics students a leg-up when they take 211, yet they are likely the students least in need of it. Will this increase the bimodal nature of student success in EOSC 211?
2. EOSC353: Adjust to attract more than 3-11 students: Offer alternate years? Rename to have broader appeal? “Advertise” in Phas/Astron or Civil Eng (eg grads)?
3. Are ATSC212, ATSC405, 406 “redundant”?
4. EOSC250:
    a. What in MATH200 as coreq is important?
    b. Or – why not make it a prerequisite (or MATH253) like EOSC213?
5. EOSC410 seems quite restrictive to undergrads (and taken by only ~4-8 students).
    a. Is EOSC212 or ENVR300 necessary if “3rd yr in EOAS is included?
    b. Is that requirement even necessary? (Probably – but worth discussing because students outside EOAS might be attracted).
    c. Could single requirement of eosc211 be loosened? Especially if CPSC203 and 210 are required.
    d. In fact, are CPSC203 and 210 really required?
6. What to do about lack of *applied* geophysics for QES students (grad/ugrad)? EOSC350 is at a lower level, but “should” be required for a geophysics degree if there is no replacement for the old EOSC451/2.

8.3 PRIORITIES, SUMMER 2020

Contents

3.1 Introduction

These notes summarize discussions between May and Sept 2020 about the QuEST project’s scope and priorities. Factors contributing to discussions included:

- goals and plans in the QuEST project proposal that garnered funding;
- loosely documented options discussed at EOAS retreats in 2019 and 2020;
- previously undocumented priorities of individual faculty members;
- approaches to curricular review and renewal, based on post-secondary educational expertise within EOAS, at UBC, and from relevant literature.

There was some debate about the QuEST project's goals and priorities. Were we expecting to take concrete action towards implement existing ideas? Were we to carry out "due diligence" & background research regarding the current state of curriculum in EOAS, and the needs, expectations & opportunities for BSc graduates? Did we expect to "make changes" or "recommend actions to make changes"? What combination of these ideas would be most appropriate for steering QuEST project activities?

There was certainly a desire to take concrete steps as soon as possible. At the same time, it is recognized that the challenges imposed by 2 years of COVID did delay progress. Moving forward into 2024 and beyond, the department can hopefully find the enthusiasm, energy and commitment to tackle some selected priorities. It is hoped that the QuEST project documentation offers some viable options, with appropriate background details to help justify suggestions, roughly predict costs and commitments, and inform decisions.

The following lists represent my (FJ's) interpretation of the main priorities emerging from discussions. Rather than concrete expectations, they are lists of ideas and issues raised. They are not presented here in any particular order. If these lists are incomplete or incorrect in any way, the fault is mine, not those who contributed.

3.2 What kinds of students are targeted for a rejuvenated curriculum?

1. One question often discussed is whether students would be best served by offering traditional QES career paths (eg. geophysics) or whether to offer a more general quantitatively oriented curriculum. End-members of the discussion look like: (1) "*university education is not about setting up students for specific careers*", versus (2) "*students should be prepared to enter specific career paths upon graduation*". The reality probably lies somewhere between these two end-members. Many aspects of QuEST work relate to this conversation.
2. The students targeted by QES curriculum renewal will most likely be a small population of rigorously inclined students, perhaps ~15-25.
3. Are any such students in the ENSC and related programs?
4. There needs to be an awareness of the distinction between recommendations aimed at enhancing quantitative capabilities of "all" geoscience students versus those targeting the teaching of quantitatively inclined specialists.
5. Care needs to be taken to avoid describing aspirations for *undergraduate* programs at the *graduate student*
6. Is there energy and justification for developing a new consolidated degree program encompassing a range of disciplines that is both appealing and develops rigorous capabilities such as process modelling & data science? The pros & cons and costs & opportunities are still debated, but a more practical, incremental pathway may be more likely to succeed.

3.3 What changes to existing EOAS programs are appropriate at this time?

Discussions during summer 2020 certainly revealed a desire for concrete action soon. The following are specific suggestions. They are not in any particular order, nor are "costs" and requirements discussed here.

1. Gradually changing content of existing courses was discussed as more practical than introducing new courses and dropping old ones. However, given the number of new EOAS faculty between 2018 and 2024, new courses will no doubt emerge.
    a. Adjusting existing courses or building new ones should not occur in isolation. Changes should be predicated by a vision & planning sequence, otherwise progress will be piece-meal and curricular flow for students may be compromised.

    b. If gradual adjustments are intended to contribute in the long term towards a new degree specialization, then courses that are applicable within the geophysics curriculum may be the most likely candidates for evolution.
2. Could QES specializations &/or courses be consolidated into a program that is appealing and appropriate for students who would otherwise consider physics? Two examples of appropriate subject areas are *process modelling* and *data science*. There are certainly others.
    a. This would initially target ~15-25 students.
    b. Common 2nd & 3rd year, specialization at 4th year (eg solid or fluid).
    c. Consider new 3rd 4th year options in hydrology, geophysical fluids for atsc / ocgy, climate.
    d. A degree specialization name change could be considered, eventually.
3. Engage with Environmental Sciences. Ideas include:
    a. Establish an optional QES stream within the ENSC specialization involving existing EOAS courses. Ensure it is characterized to attract and inspire appropriate students.
    b. Determine if there could be QES components as part of the Faculty of Science's sustainability and ENSC ideas and aspirations. (T. Ivanochko would be first point of contact for such discussions.)
4. Examine potential joint, minor or other degree or credential options
    a. With Physics? EngPhys, a minor in geophysics? Needs inspiring marketing.
    b. Math? Maybe a credential in geophysics (geophysical fluids or inversion perhaps) or atmospheric sciences (fluids or numerical methods perhaps)
    c. Computer science? Maybe less likely, unless a friendly CPSC colleague can be convinced.
5. Who could/should be involved?
    a. A balance is needed between "too many cooks" and individuals simply forging ahead without consultation and planning. This requires careful coordination to manage varying expectations and the practicalities of curricular change within the UBC "system".
    b. EOAS faculty will want to apply their own expertise to define learning priorities. Fair enough – also engage educational expertise about curriculum design & best practices with UBC support and with reference to precedent (the geosci and QES literature).
    c. Time and energy needed to make progress is considered daunting by some. Therefore, Departmental support such as teaching or committee duty buy-outs may be important.
6. What are the key QES skills that students should develop?
    a. Faculty members are of course experts in their areas of discipline-specific research. However, most are under-informed about the needs of the non-academic occupations that students will take on after graduating. The QuEST project addresses these issues.
    b. Foundational concepts, tools & methods were discussed at Department retreats in spring 2019 and 2020 and are summarized elsewhere.
    c. Defining QES curriculum is a balance between generalities & specifics. "Academic freedom" is fine but students need to know what KINDS of problems they'll learn to solve. Appropriate program and course learning objectives must inform students as well as faculty and these objectives may require examples to clarify.

3.4 Outreach, recruiting, marketing & student support or advising

The desire to take concrete steps as soon as possible was particularly evident regarding efforts to attract appropriate students. Here are ideas that were discuss. Many have been initiated – see QuEST marketing actions and recommendations for details.

1. Outreach: target high schools and UBC's Vantage college.
    a. Ideas for targeting schools were discussed – see QuEST marketing recommendations. A primary goal is to dispel the notion that Earth sciences are "soft".

   b. Target high school teachers and career advisers, how apparently tell students that the Earth sciences do not involve much "hard science". We (EOAS) tend to reinforce this by the qualitative nature of most first year EOAS courses.
   c. However, "marketing" to these targets was recognized as challenging and time consuming.
   d. These challenges are not unique to UBC – see for example. Lyon etal 2020.
2. Improve all EOAS **and** UBC web content relating to EOAS degrees and occupations. This was done in 2020-21 but deserves as second round of improvements, ideally with advice from EOAS faculty
3. Inject EOAS context into the (then) new DSCI-100 course taught by Statistics.
4. Provide more substantial help for students to map their strengths & interests onto opportunities. In other words, improve advising so that students are more aware of rewarding opportunities and benefits of pursuing QES degrees.
5. Clarify relevant industry workforce situations and opportunities for students, based on academic, government and professional societies information.
6. Relate opportunities for physics students to QES. Start here.
7. Increased inspiring & relevant contexts for learning in existing QES courses. This means relatively minor adjustments to content, assignments and assessments, including (for example) instigating capstone opportunities that relate to occupations students may encounter in the one to two years following their graduation.

3.5 A new first year course

This was considered during deliberations to be a high priority. Unfortunately, no further work was completed other than some discussion and background research about first year students in other EOSC 1xx courses, perhaps due to lack of resources and other priorities during COVID. However, the Department could now (2023) consider whether this can be elevated again to a high priority.

See the separate page for details about a proposed new first year course, including a synthesis of earlier deliberations and resulting recommendations.

8.4 CONCEPTS, TOOLS AND PROGRAMS; EARLY IDEAS

Synthesized from deliberations during summer 2020 and at Dep't retreats of 2019 and 2020.

Contents

4.1 Program learning objectives (PLOs)

These are "generic" since they are not about any specific degree specialization. They are meant to articulate priorities and expectations for quantitative BSc degrees in Earth Science such as geophysics, atmospheric science, physical oceanography, etc.

Students will …

1. … choose and apply foundational math and physics concepts (to 2nd or 3rd year level) to address problems involving the physics of Earth or planets and describe the techniques used to explain planetary physical processes.
2. … be ready for research/industry/government positions, not limited to Earth-science related fields: transferable skill is central to what we teach (similar to physics, but more applicable)
3. … apply physical, mathematical, computational and Earth science concepts to explain and address society's challenges as they relate to geosciences. Examples include climate change, water & resource exploration & management, natural hazard forecasting & mitigation, and others.
4. … gain sufficient awareness of how observational geoscience works either explicitly or by implication during QES courses, so they can contribute knowledgeably in geoscience teams.

Comment: These are on the right track, but could be refined. Consider synthesizing a broadly applicable set of PLOs based on current PLOs for ATSC, OCGY and GEOP specializations (summarized here), with additional insights from EOAS service course PLOs.

4.2 Concepts to be learned

The table below summarizes concepts that several faculty members listed as priorities for any quantitative Earth sciences degree. Math and geophysics were emphasized but few "geoscience" concepts were listed.

In future discussions, it should be recognized that the Earth system context is what makes a QES degree from this Department unique. Geoscientific "thinking" is as distinct as mathematical or physics-based thinking, so exposure to, and practice using, observational Earth science ways of thinking do need to be incorporated into a QES degree program. This aspect can be addressed without too many "extra" courses by carefully weaving geoscience contexts into existing courses, but that needs to be explicit, by design, and with relevant components for practice and corresponding assessment.

Many of these are already taught – see the "Current EOAS course content" page. Not all concepts would be required to complete a QES degree. Also, these are not meant to map one to one onto individual courses.

Fundamental concepts	Earth-science concepts	Methods, tools, strategies
• conservation laws, mechanics, thermodynamics • equations of state, constitutive laws • waves (how? to what degree of sophistication?) • diffusion, damping, advection • signals and noise • forcing and feedback, stability, bifurcation • scientific hypothesis testing by both experimentation and observation • simulation and prediction using empirical / statistical models	• continuum mechanics (plus basic classical mechanics) • fluids, solids, porous media • GFD • convection in a variety of settings • hydrology & hydrogeology • seismic wave propagation • potential fields: gravity, magnetics, EM in context • climate physics	• ODEs and PDEs (initial and boundary value problems) • scaling & dimensional analysis • systematic model simplification, heuristic lumped (box) models • dynamical systems • numerical methods for deterministic models, discretization methods • inverse models • spectral analysis, signal analysis • data analysis, image analysis • statistics

- machine learning etc.

4.3 Course ideas

1. Austin: Predicts ~15 students / yr in a course that uses a text like Denis Hartmann's Global Physical Climatology (free if you're on our vpn). Example 3rd yr course taught at U. Washington (https://atmos.uw.edu/~dennis/321/) or grad course at https://atmos.washington.edu/~dennis/571/. Links are "old" but were valid 231006.
2. Austin: Consider broadening topics in ATSC 409/EOSC 511 (numerical methods) and offer it every year. That way, 3rd yr students experience simulation/model building as soon as they've completed ODEs.
3. A good example of a new course design can be seen for DSCI 100/ Their new, purpose built textbook and problem sets – are a good example of course design that balances fundamentals and applicability. See also a course design talk by course developer Prof. T. Timbers.
4. Brian Rose's SUNY climate modeling course, modeling software (docs) https://brian-rose.github.io/ClimateLaboratoryBook/courseware/models-budgets-fun.html
5. Haber's imaging course (proposed before 2020)
6. Heagy's rejuvenated applied geophysics EOSC 454 + grad version, hopefully to be taught in Jan. 2024.
7. Climate physics – P. Austin and R. White (details?)
8. others please …

CGS comment: Climate science is a great objective here. This is a relatively new, unique strength in EOAS, with faculty from multiple disciplines. In EOAS, "climate" is not the purview of atmospheric science, or even seen predominantly through that lens. EOAS faculty include Rachel White, Anais Orsi, Mitch Darcy, Stephanie Waterman, Valentina Radic, Mark Johnson, Christian Schoof, Mark Jellinek, Phil Austin, Susan Allen and others, making for an excellent QES climate core.

FJ comments: Agreed. "Climate science" or "climate physics" (or similar) represents a timely and appropriate opportunity for defining a QES domain to focus upon. In addition, consider developing creative ways of incorporating the Department's solid and fluid QES expertise into these courses. Also – avoid fixating on "physics" to the total exclusion of "Earth". QES is the focus but context must be included or this is not an Earth sciences degree. This may seem obvious and well understood, but it is mentioned here so the issue is visible.

4.4 Eldad's sketch for a program

(This outline may date from ~2018 and some aspects may already be incorporated into the current 2023 Geophysics curriculum.)

4.4.1 General principle

Geophysics is the physics of the earth and planets. The main disciplines are solid earth geophysics, physical oceanography, atmospheric science, hydrology.
FJ comment: agreed, except to recognize that words matter – and "geophysics" (although correct) may be understood by others more narrowly, resulting in misconceptions about what can be involved and what opportunities there are for future occupations.

4.4.2 Goals of a QES program

1. The main goal of any QES program would be for students to learn and practice the mathematical and scientific techniques needed to (a) understand the dynamic Earth, oceans & atmosphere, and (b) address corresponding societal priorities.
2. Students should also be able to explain to society and discuss common problems in the physical geosciences, including (but not limited to) climate change, water management, resource exploration & stewardship, and others.

The common thread in these disciplines are

1. Math: calculus, linear algebra and O/PDEs
2. Physics: mechanics, electrodynamics, waves, some thermodynamics, emphasis on continuum mechanics, fluid flow, elasticity.
3. Statistics: basic probability and statistical thinking
4. Computing: programming, signal processing, image processing, data science, AI / ML. (As mentioned above, choice of terminology matters. The term "computer science" implies – to some people – details about how computers work, databases, algorithms, etc. That is the domain of Dep't Computer Science, and they don't like others treading on their turf.)
5. Field & measurement techniques: data collection, wrangling and processing.

Missing from this list is recognition that an Earth science degree (as opposed to a math or physics degree) should include exposure to the unique styles of thinking necessary for tackling pressing problems related to how Earth works, including geology, hydrogeology, climate science and so on. This does not mean students qualifying with a QES degree should be able to compete with geologists or geography majors. But geoscience thinking has unique aspects that QES specialists should encounter so they can contribute effectively in the teams they will work with.

4.4.3 Major principles of the program

1. Let lowest level courses be taught at their home departments.
2. Get the students as early as possible for science courses that are not basic.
3. Go hard in first/second year on basic science and prepare students to a serious discussion about geoscience in third/forth year.
4. **FJ comment**: OK, and motivation also matters. Students learn better when context is meaningful. Early learning activities related to "why we're learning this" are well worth while. And as many learning activities (lessons, activities, assignments, projects, etc) as possible should be carried out within an explicit, concrete context. Some creativity may be needed, but including context is always feasible without compromising fundamentals. Students will learn and retain new concepts better, and they will be more highly motivated when they can personally relate to the "point" of gaining those skills.

4.4.4 Particular Courses

NOTE the geophysics curriculum was updated recently (2018?) and the following outline is essentially the same as current geophysics requirements. See https://vancouver.calendar.ubc.ca/faculties-colleges-and-schools/faculty-science/bachelor-science/geophysics

Courses should include settings that involve "*thinking about the physical Earth*". Focus is to be on specific skills (like ODEs etc.), but they are tools to address meaningful situations, not only abstract notions. Take-home messages for students are about "transferable skills" (i.e. methods), but capabilities fostered by learning in context will include >motivation to learn at the time, >deeper understanding, >better retention, and >abilities to apply “methods” in novel settings. These “benefits” need to be clearly and repeatedly emphasized for students in the courses they take (as per recommendations regarding “transparency in learning and teaching”, Winkelmes, 2023).

Year 1

- Calculus 1 & 2 (MATH 100/102/104 & MATH 101/103/105 & MATH 200)
- EM and waves (PHYS 107 & 108. These provide crucial introductory exposure. Students do not yet have multivariable / vector calculus)
- Data science (DSCI 100 represents first exposure to stats & programming. EOSC211 is in 2nd yr)
- A new first year course? “the quantitative Earth”, “climate physics” or equivalent. (is this to be a “required elective”?)

Year 2

- Statistics may be managed on “as needed” basis. (DSCI100 is req’d) (Stats 200 may not be very helpful for us; mainly pvalues / type I / type II errors, etc.)
- Linear algebra (MATH 221/223) (Be careful to not students to progress too quickly. Gaining mathematical “maturity” takes time, although a few can advance quickly.)
- Mechanics (CGS PHYS 107)
- Programming (EOSC 211)
- Intro physics of earth and planets (EOSC 212) (212 has little “physics” – it is more like a first exposure to scientific earth and planetary science literature.).
- Vector calculus and intro to differential equations / math modelling in context (EOSC 250)

Year 3

- ODEs, PDE’s (MATH 215 & MATH 316/PHYS 312)
- Continuum mechanics (EOSC 352 [“cont. dynamics”],
- Fluid dynamics (EOSC 352)
- Signal processing (EOSC 354)
- Image processing / remote sensing (Currently no requirement, Eldad has interest in developing) (Is this the right level? Maybe an elective?)
- Data science: AI/ML (EOSC 410)

Year 4

Many of these should be considered “technical electives”. Students should seek advice to identify choices consistent with their interests and abilities. Based on student feedback, they need to be able to meet professional requirements if they want to go that route.

- Elasticity via seismology (EOSC 353)
- Geophysical fluid dynamics (potentially EOSC 477 / ATSC 414 – currently dormant, not required, potential for co-listing with EOSC 512)
- Physical oceanography? (EOSC 471)
- Upper level ATSC?
- Geophysical solid mechanics (no obvious course – probably rely on 353 to cover this)
- Hydrology and fluids in the earth – EOSC329 Groundwater.
- Climate change or physics (Phil & Rachel working on EOSC595, and a split of 340 into quantitative / non-quantiatitve is on the cards, we’d use the quantitative version here)

- Will most likely retain EOSC450 (currently essentially "potential fields", which is fine).
- Retain EOSC453 (Physics of the Earth and other planets) as a common capstone across the program?
- May need to align multiple options with corresponding grad course and run in alternate years to make viable.
- EOAS-based courses:
  - Likely core pathway 211,212,250,352,354,410,453
  - Options out of 353,450,477,329, Climate
- Note: 353,329 are 3rd year, others are 4th year / undefined. This is apparently not a UBC graduation requirements issue.

4.4.5 Other issues to adjust in existing geophysics curriculum, aligned with the above

Note at 2023, these points may be out of date.

- Stratigraphy course requirement EOSC222 redundant if broadening scope of GEOP degree as advertised; drop and free up this space? Or make it 222 or EOSC2xxx / Other Subject 2xx?
- EOSC211 – scope for making optional with other computing offerings across campus? Not a priority, and may not be popular in EOAS as an idea
- Thermodynamics course (currently PHYS203) – make this PHYS203 or CHEM205; absolutely needed in program?
- EM PHYS301 already not widely taken – not sure I really see the rationale but there is precedent. In the context of broadening geophysics, we could make this one of PHYS301, EOSC350 (applied geophysics), MATH345 (applied nonlinear dynamics and chaos, MATH215 is a prerequisite but included in GEOP curriculum, must score 68% or higher – this covers the dynamical systems tools area). The proposed set of options covers a greater range of future specializations. Can add (i) ATSC specialized option if available and (ii) Catherine's planned global geophysics class here too.

8.5 QUANTITATIVE EARTH SCIENCE ORGANIZATIONS

These just a "taste" of professional and academic organizations that are not universities. Most are North American focus, but some are international (eg AGU, IEEE). There are also analogous European and Australian organizations. The formal professional regulators (under provincial jurisdiction in Canada – such as EGBC) are not included in this list.

1. **AGI** (American Geosciences Institute)
   a. **Geosciences Careers Brochure** and video.
   b. **Infographic** about the Geoscience Workforce from the Preparing Our Workforce (POW) initiative. Its goal is to help students entering the workforce redefine what it means to have a career in geoscience.
   c. **Career compasses**: These provide options, tips, suggestions, and strategies for pursuing critical skills, experiences, and competencies for geoscience careers. The collection is intended to grow with time.
2. **AGU** (American Geophysical Union):
   a. All **EOS** (AGU's magazine) articles in the "Education & Careers" subject area.
   b. Individual geoscientists' **career profiles**: 14 in July 2023, 19 in July 2022, 17 in Aug 2021.
   c. https://findajob.agu.org/ is a searchable collection of mostly academic or "higher level" scientific positions.

3. GROW, the "**Geoscience Resources on Opportunities in the Workforce**" website.
    a. **GROW** is a set of resources for students, mentors, and departments to explore non-academic careers pathways & occupations, to view career profiles, and to learn how to search for geoscience work positions.
    b. This **sitemap** shows the scope of content.
4. **Geocareers**: An online asynchronous course from the EarthScope consortium, designed to provide an overview of the geoscience profession, with specific examples in geophysical applications.
5. **SERC**, Science Education Resource Center at Carleton College
    a. **Introducing Geoscience careers:** From the SAGE 2YC site at at SERC: resources for students. (SAGE 2YC = Supporting and Advancing Geoscience Education at Two-Year Colleges.)
        i. What do Geoscientists Do?
        ii. Geoscience Degrees and Careers
        iii. Employment in the Geosciences
        iv. Employer Perspectives
        v. Professional Society Career Resources
    b. Explore SERC for other education and career-support resources.
6. **Geoscientists Canada** – home page.
    a. About this regulated profession; what geoscientists do, and how / why it is a registered profession.
    b. Plenty of information about careers, becoming a registered professional, practicing in Canada and more.
7. **Canadian Federation of Earth Sciences**
    a. A careers page; includes profiles/interviews of 9 different geoscience professionals.
    b. All about Earth sciences and earth science careers. This site is from 2009.
       Information about salaries and other details is of course out of date, but descriptive information is relevant and well presented.
8. **Occupational Outlook for Geoscientists** from the US Bureau of Labour Statistics:
    a. The focus is USA but relevant for North America. Comprehensive information is provided about: >What Geoscientists Do; >Work Environment; >How to Become a Geoscientist; >Pay; >Job Outlook; >State & Area Data; >Similar Occupations; >More Information including Links to O*NET.
9. **Other professional societies** – look for information they provide about careers, hiring, students, and similar topics.
    a. SEG, Society of Exploration Geophysicists
    b. GSA, Geological Society of America
    c. KEGS, Canadian Exploration Geophysics Society
    d. KEGS Foundation, the scholarship adjudication branch of KEGS
    e. Also search for "Canadian geophysics societies".
    f. IEEE, Institute of Electrical and Electronics Engineers (international)
10. Oceanography links? Ask ocgy faculty
11. Atmospheric sciences links? Ask atsc faculty.

Possible improvements for this page:

1. It could become an EOAS website page (e.g. via the career paths page) for public consumption (i.e. recruiting)? Information may evolve but probably not rapidly.

2. Long lists are rarely read. What alternatives for EOAS website or the Canvas site. Therefore consider a table of icons similar to the Career Pathways page at GROW, instead of this list.
3. Can interviews from EER 2023 be added?

8.6 Activities for Exploring Career Options

Current and prospective students will benefit from seeing evidence that meaningful and rewarding occupations exist and are in demand. A list of relevant sources is given separately; see the QES Professions page.

This page summarizes two examples of concrete actions taken at two institutions:
(A) a career-preparation "distributed assignment" (i.e. several parts to an assignment in one course throughout the term) and
(B) an optional course about career options in the geosciences.

Source for both is Anne E. Egger & Karen Viskupic, "*Facilitating career exploration early in the curriculum through coordinated reflection assignments*", presentation at EER 2023, accessible via the workshop outline.

(A) A 2nd year assignment at Central Washington University (A. Egger)

A 4th year seminar on careers was found to be **too late,** according to students. Therefore an assignment for 2nd year students was developed. Seven 20-30 minute interviews with Alumni; view one each week and answer one single question. The goal is to reflect on your priorities, interests and opportunities for after graduation, and gain insights from alumni about what steps could be taken to support your journey after graduating.

1. **Alumni interviews** collected on Zoom and recordings. Questions posed to **Alumni**:
   - What is your current job?
   - What do you do day-to-day?
   - If applicable: When/why did you decide to get your Masters?
   - How did you go about looking for a job when you graduated?
   - How did you get the current job you have? (And how did you get other geology jobs if you've had others?)
   - Do you have any advice for students just entering the geology major?
   - Do you have any advice for students graduating soon?
2. **Student assignment**: One of these interviews assigned each week. Task: "*After watching this week's interview, answer* ***one*** *of these questions.* ***What did you hear in the interview*** *that could help you…*
   1. *…decide what you'd like to do after graduation?*
   2. *…plan how to go through your remaining time at CWU?*
   3. *…learn what kinds of geoscience-related jobs are interesting to you?*
   In other words, pick something in the interview that applies to you (or resonated with you) and tell us about it."
3. **Results:** 303 responses (i.e. "reflections") were coded by instructors to learn:
   - Which question was answered?
   - What were dominant priorities and perspectives emerged?
   - Example of results: counts of coded responses to the question "*What to do with remaining time at university?*"

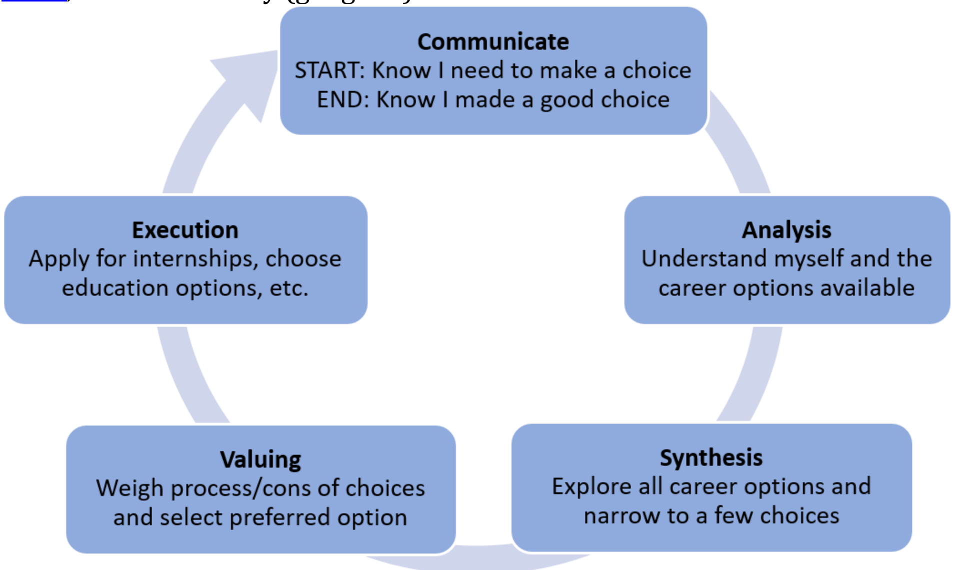
A possible EOAS version of this assignment:

- Choose which course(s) to do this in – see the QuEST curriculum map. Perhaps EOSC212? 250? ENVR200?
- Could offer 2-3 cases for each assigned instance, or simply assign one for each instance of the assignment.
- Perhaps 4-6 per term? Must be > 3 so students gain familiarity with the task and see a range of examples. Once a week may be over-kill.
- If not alumni interviews, perhaps search for written career profiles at AGI, AGU, others?
- Final assignment could involve sharing anonymous results of individual reflections with the class and either discussing, or selecting several that are different from your own but that resonate with you.
- A possible final question: "*write a sentence or two expressing whether this assignment was useful to you, if so how, and if not why*".
- Later on, use results to showcase student perspectives on careers in geoscience.
- Comments:
    - Needs alumni interviews, or profiles from AGU and/or other sources. Professional societies and non-academic colleagues aught to be sources for 30min interviews.
    - The "view and reflect on a video" assignment is only one of many possibilities.
    - Other skills to develop: networking, LinkedIn, planning or planning templates,
    - What options regarding career profiles, other than videos of alumni interviews? Some ideas are here.

(B) One-credit elective course for career exploration & planning

- Presented by K. Viskupic at EER 2023 – slides.
- Targeting 2nd or early 3rd year students.
- Developed to be consistent with cognitive information processing (CIP) theory (slide 6) and the **CASVE model for career problem solving and decision-making** originally due to Sampson et.al.

1999, but used widely (google it).



- Sampson et al. 1999 is rather theoretical but their basic decision making flow chart can help identify what "step" any initiative is actually targeting. Makes career-preparation efforts more "intentional" and targeted.
- Sample Learning goals:
    1. Analyze your interests, values, and abilities as related to potential careers.
    2. Describe career options in the geosciences that match your interests, values, and abilities.
    3. Determine the skills and experiences needed to pursue careers of interest.
    4. Tailor your job/internship applications so that they are competitive.
    5. Write a career development plan.
- Table summarizing the course goals and activities; last slide from the presentation:

Course outcomes: At the end of the course, you will be able to…	**Key Course Activities**	**CASVE Cycle Alignment**
Analyze your interests, values, and abilities as related to potential careers	– Students analyze and **reflect on their personal interests, values, and abilities** as they relate to a work environment	Communication, Analysis
Describe career options in the geosciences that match your interests, values, and abilities	– Students **explore Department of Labor and job search websites** for career research – Students **interact with geoscience professionals** (mostly alumni) in a variety of positions as part of two career panels	Analysis, Synthesis, Valuing
Evaluate the skills and experiences needed to pursue careers of interest	– Students **learn about and reflect on desired workforce skills** (e.g., Mosher & Keane, 2021; Shafer et al., 2022) – Students **learn about the processes for professional licensure** in the geosciences, and **learn about graduate school** applications and admissions	Synthesis, Valuing
Tailor your job/internship applications so that they are competitive	– Students **create general and targeted resumes**, **write a cover letter**, and **prepare for an interview**	Execution
Write a career development plan	– Students **write a step-by-step plan** to achieve a career-related goal	Execution

- Based on analysis of surveying, focus groups, & reviewing student work (30 students in 3 yrs), results suggest that (in this case):

- Initially, students knew little about career options for geoscience majors, and did not understand how job titles related to their interests.
- Students appreciated the guidance provided by the CASVE model. Structuring career planning into small steps with concrete examples of aspects (e.g. networking) reduced feelings of being overwhelmed.
- Reflection helped students relate to geoscience careers, and increased their confidence with respect to planning for, finding and getting appropriate jobs.
- Career panelists provided external perspectives and variety regarding career options. They highlighted important courses, key experiences, and details about work environments.
- This class seems to be working: >Students learn about themselves, >Students learn about career options, >Students connect what they know about themselves and career options, >Students make a plan, >Students feel prepared

Adaptations suitable for EOAS

1. Having a respected framework (CASVE) is likely useful for structuring career preparation experiences even if implemented within existing curricular context (i.e. not building a whole new course).
2. The career awareness and career preparation components of a department-wide Canvas resource for students could be structured in terms of the framework.
3. Short assignments (like option 1. above) could usefully be framed in terms of the CSAVE career preparation model.
4. Comments:
    1. Who in the Department is willing to take on delivery and maintenance of career preparation assignments?
    2. How to inspire colleagues? See workshop notes on getting Buy-In from Colleagues.
    3. Where within the curriculum can this be incorporated? Could be small scale in one or two courses, or a lab activity. Could also be a catered "event" – evening or 1/2 a weekend day, etc. Ideas would need discussing.
    4. Consider choosing which specific activities are most important and implementing them in a seminar or existing course: eg, developing skills related to networking, using LinkeIn, carryout out career planning, or other ideas worked on with these 11 docs.

8.7 GROW Site Map

The **Geoscience Resources on Opportunities in the Workforce** (GROW) resource was funded by NSF. It is probably dated late 2022, although not noted anywhere. Dates and maintenance plans have been requested via the "contact" form on the about page.

This site map provides hints as to content and scope.

1) Home
    a) about
        i) Geoscience **jobs are plentiful** and salaries are competitive.
        ii) **Career paths** in the geosciences are varied, fluid, and adaptable.
        iii) The **workforce** by the numbers
    b) For geoscience **students**
        i) Find your fit
            (1) Picture a Geoscientist
            (2) Join a Community

        (3) Unearth Your Future: Online Course
        (4) Explore Jobs by Sector
    ii) Advice from 3 recent graduates
  c) For Geoscience **departments** (a page with graphics, descriptions, videos, & lots of pointers)
    i) Earth Science Literacy
    ii) Transferable Skills
    iii) Evolving Workforce
    iv) Career Values
    v) Diversity and inclusion
    vi) Online course: **Unearth Your Future**. *This is a free, asynchronous 3-5hr online course geared towards undergraduate students that shares new perspectives on geoscience and geophysics careers, workforce information, and contains key strategies for conducting a successful job search.*
    vii) References: 19 peer reviewed articles or online resources. Most recent is 2021.
2) **Career Pathways**:
  a) Explore Geoscience Career Pathways
    i) Who are geoscientists? What do they do? How can you get started in this field? Video from IRIS Earthquake Science, Youtube, 5:30 mins.
  b) Resource pointers:
    i) Geoscience Careers: AGI video & brochure
    ii) AGI Career Compass: Infographics
    iii) Finding Your Fit: AGU Webinar
    iv) Think Outside the Box: IRIS Webinar
    v) Career Cornerstone: Website
    vi) SAGE 2YC Career Info: Website
    vii) PROGRESS Careers: Website
    viii) Geology Career Paths: Interactive exploration
  c) What level of education do you need? (Details via a link for each item.)
    i) B.S.: Broad education in geoscience. Typically required for entry-level positions in industry, government, education, and non-profit sectors.
    ii) M.S. Further training in a geoscience sub-discipline. Required for some entry-level positions. Most likely to promote career growth.
    iii) Ph.D. Specialization and original research in a geoscience sub-discipline. Required for most academic and research scientist positions.
    iv) Licensing: Required in some states for geologists that offer services to the public. Uses the ASBOG® Fundamentals of Geology Exam.
    v) Certifications: Further preparation for advancing a geoscience career (for example, science communication programs or Geologist-in-Training Certification).
    vi) Professional degrees: For those interested in environmental law or medical geology.
3) Career **Profiles**: Pointers to **20 different collections** about geoscience career paths and the day-to-day work life of geoscientists, each with unique backgrounds and skills, working in a variety of fields and occupations.
4) **Jobs by Sector**. Each chapter has sections:
  i) *Get Started*, ii) *Ask and Expert*, iii) *Explore Employers*, and iv) *Career preparation*.
  a) Government
  b) Industry
  c) Non-profit
  d) Education
  e) Policy
  f) Communication
  g) Job Boards: 32 job boards, plus “Key Words” for searching purposes.

8.8 AI AND LEARNING

This page contains some evolving thoughts about use and abuse of AI as part of learning and teaching. Thoughts are random initially (Sept. 2023).

8.1 Generative AI and the KASH model of learning

Learning can be considered in terms of gaining or improving new knowledge, attitudes, skills and habits (KASH). (This is only one of many models for "domains of learning" but it is useful for this discussion.) **Knowledge** is the "*stuff we know*", **skills** are "*capabilities or things we can do*", **attitudes** include "*awareness of self, situation, others and motivation*", and **habits** are "*things you do regularly or repeatedly*".

Technology has been making **knowledge** increasingly available to all:

However, it takes **practice** and **feedback** to improve skills, and it takes a certain **maturity** within the discipline to gain attitudes that are **perceptive, creative and productive**. Generative AI is beginning to make certain "knowledge" increasingly available. HOWEVER, a human mind requires ***effort*** to become good at something that could be considered a **skill**, and **attitudes** are nuanced and complicated – they take time to develop.

Education has been shifting from a focus on **imparting knowledge** to **fostering development of skills and attitudes**, but that shift is still in progress. Maybe the emergence of generative AI will help us all accelerate that shift towards
– teaching as *providing opportunities for students to practice skills,*
– instead of teaching as *delivering facts and figures*.

That will require that teachers **adjust** their abilities from being expert presenters to becoming expert facilitators, assessors, and deliverers of timely and effective feedback. There is still room for selective delivery of knowledge – especially in the form of story-telling, but "teaching" no longer has to include the repetitive delivery of content that is obtainable elsewhere and "on demand".

8.2 Notes and pointers

1) Sources of information, workshops and policies at UBC – needs links.

2) What is generative AI? sources:
   a) Wikipedia
      i) on generative AI
      ii) on ChatGPT
   b) At UBC:
      i) More generic information about generative AI.
      ii) ChatGPT Q&A at UBC's Academic Integrity website. 9 FAQs addressed.
      iii) UBC Library's 6-page section about generative AI and ChatGPT.
      iv) Starting point for CTLT's several pages about generative ai.
      v) For more, try putting *"generative ai" site=ubc.ca* into your google search engine.
   c) Beyond UBC
      i) CBC Radio FrontBurner episode: ChatGPT in university: useful tool or cheating hack? link with audio plus Transcript.
      ii) Magazine piece about ChatGPT in Toronto Life, by journalist and writing instructor at U. of Toronto.
      iii) IEEE is active in this area – for example "How ChatGPT Could Revolutionize Academia".
      iv) Likely to be more to come.
   d) Notes to be added from three CTLT 1-hr workshops in Sept & Oct 2023. See links to resources on that page, especially CTLT's new GenAI resources home page.
   e) How ChatGPT Could Revolutionize Academia ; The AI chatbot could enhance learning, but also creates some challenges. An expert opinion piece in the IEEE Spectrum magazine, February 2023.
   f) Discussed in EOS, (McGovern, 2021): "*Artificial intelligence (AI), machine learning (ML), and data science provide flexible, scalable, and interpretable approaches to harness the growing volume of available data that can help us improve the understanding and prediction of a wide variety of geoscience phenomena, including natural hazards, climate change, and severe weather events.*"
   g) Also in EOS, Realizing Machine Learning's Promise in Geoscience Remote Sensing.
3) Implications
   a) The end product alone, of a learning activity (eg – code written) may not be sufficient for assessment. The process, sequence of steps, thinking involved, etc. may be more important for assessment. Perhaps a flow chart, or pseudo code, etc. Something a text-based AI can not produce. Weekly interviews are used in an Engineering Physics project lab course (see next item).
   b) Generative AI in education at UBC: "A Learning Renaissance", written for alumni in the UBC Magazine. Good read – 5 minutes only!
      i) "Tools are changing at a pace that is almost impossible to keep up with"
      ii) It isn't enough to become more tech-literate – students have to become more tech-critical.
      iii) Instead of worrying about students using AI for homework … "He traded graded homework for weekly interviews, ensuring that students can communicate what kind of code they developed and how deeply they understand its function.".
      iv) "As intellectual tasks are increasingly offloaded to machines, today's students are preparing to be tomorrow's workers, learning less about the technical minutiae of their profession and more about how to oversee the machines that will be performing those tasks for them."

8.9 For Instructors

This message was provided to instructors by James Charbonneau (Faculty of Science Associate Dean, Students) at start of term in late August, 2023. It highlights **key resources related to undergraduate teaching and student support.** We hope that with these resources you will feel equipped to direct students to appropriate academic and non-academic support during the upcoming year.

Instructional Resources

- Especially if you are a new instructor, review the Faculty Primer, which covers the basic information about teaching at UBC.
- Find out who your teaching point-of-contact is in your department. In many departments, this is an associate head or undergraduate chair who oversees undergraduate education.
- Ask your teaching point-of-contact questions about departmental, Faculty of Science, and institutional policies and norms. UBC is a complicated institution, and it is not expected new instructors know how everything works right away.
- Disruptions during teaching in classes is very rare, but be prepared by reviewing the guidance for dealing with classroom disruptions. It provides you steps if your class is disrupted by an outside group or a student in the class, or if campus security or the police visit unannounced.
- Learning Technology support:
    - UBC's Learning Technology Hub will provide support through LT.hub@ubc.ca and the LT Hub website
    - Skylight can provide support through LT.support@science.ubc.ca
    - The Skylight Inclusive Teaching page contains several excellent resources about syllabi, course design, and assessments that contribute to students' learning, wellbeing, and sense of belonging.

New Course Design, AI and Academic Integrity Resources

- *All course syllabi should include information about course requirements and expectations.*
- The Academic Integrity website has examples about how to communicate your expectations regarding **generative artificial intelligence (genAI, e.g. ChatGPT)**. Be proactive about communicating your expectations about genAI and, if needed, adjusting your course design to mitigate or leverage genAI.
- The AI in Teaching and Learning website at CTLT is a central hub where you can learn more about AI tools, resources, and events.
- UBC has an **educative approach to academic integrity**. The foundation of our educative approach relies on instructors teaching about and clearly communicating their expectations for academic integrity. To help you with this, there are academic integrity modules you can use with your students and example syllabus statements on the Academic Integrity website.
- When you suspect **a breach of your course's academic integrity** requirements, it is important you follow the academic misconduct review process. The process is described on the Academic Integrity website, which has resources for both students and instructors.
- The Faculty of Science participates in the new **Diversionary Process**. The Diversionary Process does not change procedures at the instructor or department levels. This Academic Misconduct Handout provides the Faculty of Science academic misconduct procedures for instructors and departments. While you do not need to be overly investigative, we ask that you address every instance of suspected academic misconduct in your course.

Health, Wellbeing, and Academic Concessions

- **Being physically and mentally healthy** is part of having a successful year. UBC's Communicable Disease Prevention Framework mentions that a daily health check is important for noticing when you may be getting sick. If you are sick, stay home.
- Students should not feel pressure to put others at risk to maintain their academic progress. **A concession policy in your courses** that allows students to drop or make-up missed assignments due to illness will communicate to students that you expect them to stay home when they are sick.
- There are **reasons beyond physical illness,** such as the death of a family member or religious observances, that may cause a student to miss assignments and midterms. The Instructor Guide to

Handling In-term Concessions provides information about how to support students with these and other issues that arise during the term.

- Sometimes students need to **miss their final exam** due to illness or unanticipated personal circumstances. To request permission to write their final exam at a later date, students apply for Deferred Standing ("SD"). Students apply to their home Faculty's advising office. Refer to this instructor guide for more details about the process for BSc students Deferred Standing – Guide for Instructors teaching Science courses. Faculty Advising offices may request a grade breakdown for students applying for an SD. We would appreciate timely replies to these requests that include the detailed information requested (e.g., grades on midterm exams vs. assignments).

Supporting Students Experiencing Unanticipated Challenges or Distress

- **Stress is an expected part of university life** (and life in general), but stress or anxiety that significantly interferes with students' learning and wellbeing may indicate a student requires additional support. Become familiar with the Green Folder, which describes the range of challenges students may be facing, provides guidance for having a conversation with a student in distress, and resources/supports for students at various levels of distress.
- It can be helpful to show students this scale, so they understand where they are on it.
- There will be times **when students reach out to you** about serious and/or persistent issues that require support beyond what you can or should provide.
    - In this situation, refer the student to the resources in the Green Folder and submit an Early Alert. An Early Alert is a way to connect a student with UBC or Faculty of Science resources.
    - For example, the student may get priority to see a counsellor.
    - They will also be connected to a Science Advisor who can help them look at strategies for completing courses or, if necessary, withdraw.
    - We encourage you to submit an Early Alert for a student in distress or if you have academic concerns about a student (e.g. unusually poor academic performance).
- A student may also **disclose something very personal to you,** such as being a survivor of sexual violence.
    - The Teal Folder is a guide about connecting students to the Sexual Violence Prevention and Response Office (SVPRO).
    - **Do not** submit an Early Alert for students that disclose sexual violence to you. Follow the steps in the guide.

Reminder of Key Policies

- Students have the right to view their graded work, in particular, their final exams. The policy outlining the timelines and processes for this is described in the Calendar. Your department may have procedures worked out to streamline this process, especially in large multi-section courses. Reach out to your department teaching point-of-contact for advice about how to handle exam viewing requests.
- No midterms or formal exams are allowed in the last two weeks of the term. There is an exception for bi-weekly quizzes and lab exams. The Calendar describes the details of the policy about the use of formal exam periods.

8.10 PROFILE – FJ

This page is an example of one way to profile alumni or other professionals.

Francis Jones, MSc, Geophysicist

Previously: electrical engineer; oil/gas well-logging engineer, mineral exploration instrumentation developer, consulting geophysicist, geophysics/geoscience educator.

Currently: geoscience education development specialist in UBC's Department of Earth, Ocean and Atmospheric Sciences (**professional web page**).

Career pathway

An early interest in technology led initially to an electrical engineering degree. After 2 years applying new skills outdoors in the oil/gas industry, I started an MSc degree in geophysics at UBC, developing a portable ice-depth radar system for glacier research. The list of job titles above shows that this technical and Earth science background has enabled 35 years (and counting!) of satisfying and diverse professional activities.

The figure shows a new (in 1986) portable ice-depth radar instrument for measuring glacier thickness being tested over a seasonal subglacial lake under the margin of the Kaskawulsh Glacier, Yukon Territory (60°46'32.2″N 139°07'36.3″W). This satisfying combination of physics, instrumentation, fieldwork and data science contributed towards understanding glacier drainage and resulting annual flooding.

Rewards and examples

Applying math, physics, computing and engineering to address important challenges is the biggest reward. For example, ice-depth radar is now commonly used for climate studies, water-source investigations, hazard assessments and other applications. Designing new tools & techniques for mineral exploration and geotechnical geophysics enables more effective and responsible work related to meeting society's needs for resources and infrastructure.

Providing expertise in support of community projects is always particularly satisfying. In one consulting job, I provided field and technical expertise to complete a magnetic survey over an Alaskan community's coastal lagoon which helped clean up masses of metallic waste left by decades of military activity.

And now, developing and sharing educational best-practices tailored for geoscience learning (especially geophysics) is helping improve the learning that future geoscientsts need to address the challenges at the intersection of humanity and our Planet Earth.

8.11 EOAS COURSES MAPPED ONTO THE EGBC "SELF-CHECK" REQUIREMENTS

PDF included below.

8.12 Advising tool for geophysics (spreadsheet - PDF)

PDF included below.

8.13 List of Geophysics Scholarships

PDF included below.

8.14 Notes about EGBC registration

PDF included below.

8.15 Capstone experiences; Advice from CTLT – report

PDF included below.

8.16 Math/Geoph career preparation; Advice from CTLT - report

PDF included below.

8.17 INTERACTIVE CURRICULUM MAP WEBSITE

This web site includes interactive graphic maps of QES course dependencies for 2nd, 3rd and 4th year courses, including reference to courses outside EOAS (several coupled web pages).

8.18 Curriculum map observations Report

PDF included below.

8.19 Pre-requisite competencies

Web page; Expected capabilities by subject (not course) for each EOAS quantitative courses.

ENGINEERS & GEOSCIENTISTS
BRITISH COLUMBIA

Geophysics
Course Equivalent Listing

Updated by UBC, Dep't EOAS, Nov 2023

Preliminary; awaiting EGBC approval.

Name: ______________________________________ User ID:________________

Instructions for **advisors** and **applicants** for registration as a professional **geophysicist**.
Please review these instructions carefully.

Prior to beginning, please ensure that you have reviewed EGBC's Guideline to Completing Geoscience Checklists & Course Descriptions.

1. When preparing your list of courses for accreditation, you can list each relevant standard single-term course **only one time** on the entire checklist. The exceptions are EOSC 449 (honors thesis) or a 6 credit directed studies. Each of these may be used twice, once for technical communication and once for a discipline-specific course. See an advisor for assistance.
2. Courses you list need to correspond to the course codes that appear on your transcript from the original institution at which you took the course. For example, if you transferred a course from another institution and received transfer credit, write down the institution and course code from the original institution that appears on that original transcript.
3. Courses must be acceptable for credit in the UBC (Vancouver) Faculty of Science or Faculty of Applied Science.
4. NOTE: these courses lists may not be exhaustive, and some courses listed may not be available at the time you want to take them. This is because university departments can change the courses they offer from year to year. **If a course is not included on this list but you feel strongly that it should count, please list the course with explanation separately in the final table.**
5. Field experience is required – see Group 2A, COM-A4 and its footnote.
6. Prior to beginning, please ensure that you have reviewed the Guideline to Completing Geoscience Checklists & Course Descriptions at https://www.egbc.ca/getmedia/26ae8255-3c16-45b0-9845-73b49304ac6a/Guideline-to-Completing-Geoscience-Checklist-Course-Description.pdf.aspx (last checked November 2023).
7. Please read bullet notes above each table carefully.
8. For each course include the code, number, institution as follows, "EOSC 211, UBC".
9. The geophysics program requirements at UBC are in the UBC Calendar at https://vancouver.calendar.ubc.ca/faculties-colleges-and-schools/faculty-science/bachelor-science/geophysics (last checked November 2023).

This course list reflects the Engineers & Geoscientists BC's (EGBC's) adoption of the 2019 version of the Geoscientists Canada Geoscience Knowledge & Experience Requirements (GKE).

Group: 1A – Compulsory Foundation Science `

- **All 3 courses are Required.**

Category	Number	Subject	(Institution Name) Course Commas mean "or"	Applicant: list your courses here (Recommendations in brackets)
	FS-A1	Mathematics (1 semester)	MATH 100, 102, 104, 120, 180 or 184	(see GEOPH calendar)
	FS-A2	Physics (1 semester)	PHYS 106, 107, 117, 101 or 131	(see GEOPH calendar)
	FS-A3	Chemistry (1 semester)	CHEM 121, 111 or 141 or both CHEM 110 and 115 or both CHEM 120 and 115	(see GEOPH calendar)

Group: 1B – Additional Foundation Science

- **6 required**
- **You may report a maximum of 2 courses in any one subject.**

Category	Number	Subject	(Institution Name) Course Commas mean "or"	Applicant: list your courses here (Recommendations in brackets)
	COM-B1	Mathematics	MATH 101, 103, 105 or 121	(see GEOPH calendar)
	COM-B2	Chemistry	CHEM 123 or both CHEM 130 and 135, or any 200 level or higher CHEM	(see GEOPH calendar)
	COM-B3	Physics	PHYS 108 or 118 plus 119 or 109 or any 200 level or higher PHYS	(see GEOPH calendar)
	COM-B4	Biology	BIOL 112, 121 or any 200 level or higher BIOL	
	COM-B5	Computer Programming	EOSC 211, 213, CPSC 103, 110, APSC 160, or any 200 level or higher CPSC with programming content	(EOSC 211)
	COM-B6	Statistics	DSCI 100, STAT 200, 251, BIOL 300, or GEOG 374	(DSCI 100)

Group: 2A – Compulsory Geoscience

- **All 4 courses are required.**
- **One course must be completed in each of the 4 subjects.**

Category	Number	Subject	(Institution Name) Course Commas mean "or"	Applicant: list your courses here (Recommendations in brackets)
	COM-A1	Mineralogy & Petrology	EOSC 220, 221, 321, or 322	(EOSC 220)
	COM-A2	Sedimentation & Stratigraphy	EOSC 222, or 320	(EOSC 222)
	COM-A3	Structural Geology	EOSC 323	(EOSC 323)
	COM-A4	Field Techniques[1]	EOSC 223, 328 or 428	(EOSC 223[1])

1 NOTE: **Field work** during co-op term or summer work may be acceptable for COM-A4 if instruction can be shown to have been provided as part of the field work experience.

Group: 2B – Foundation Geophysics

- **5 of the 6 courses are required**
- **Apply only one course per subject.**

Category	**Number**	**Subject**	**(Institution Name) Course** Commas mean "or"	**Applicant: list your courses here** (Recommendations in brackets)
	FGP-A1	Digital Signal Processing	EOSC 354	(EOSC 354)
	FGP-A2	Global Geophysics or Physics of the Earth	EOSC 453	(EOSC 453)
	FGP-A3	Seismology or Seismic Methods	EOSC 353	(EOSC 353)
	FGP-A4	Exploration Geophysics	EOSC 350 or 454	(EOSC 350)
	FGP-A5	Radiometrics or Gravity & Magnetics	EOSC 450	(EOSC 450)
	FGP-A6	Electrical & EM Methods	EOSC 350 or PHYS 301	

NOTE: If you have taken all six courses for Group 2B, apply one of these six in Group 2C below.

Group: 2C – Other Geophysics

- **9 courses are required from the 58 subjects in this table.**
- **Multiple courses can be entered in each subject for this table only.**
- **Courses must be chosen from at least 4 of the "Categories", e.g. Communication, Earth and Planetary Geoscience, etc.**
- The GKE requirement list of geophysics subjects (the Geophysics column of Table 3, pgs 7, 8, 9) notes that "These lists are not meant to be exhaustive". Therefore, other geophysics topics (eg. inversion, machine learning, planetary geophysics, etc.) may be acceptable for Group: 2C courses.
- See also the last item "Other relevant geophysics courses".

Category	**Number**	**Subject**	**(Institution Name) Course** **Bold** = a UBC geophysics requirement. Commas mean "or"	**Applicant: list your courses here** 'NA' = used elsewhere
Applied Math & Physics	GP-C1	Calculus	**MATH 200**, 217, 226, 227, 253, 254, 264 or 317	(see GEOPH calendar)
	GP-C2	Computer-Controlled Instrumentation	Some ELEC, ENGR or PHYS courses may apply.	
	GP-C3	Condensed Matter Physics	PHYS 412	
	GP-C4	Continuum Mechanics	**EOSC 352**	(EOSC 352)
	GP-C5	Digital Signal Processing	EOSC 354	NA
	GP-C6	Electromagnetic Theory	PHYS 401 or 454	
	GP-C7	Electronics for Scientists	ELEC 203, Both of ELEC (204 and 205), ELEC 301, PHYS 309 or 319	
	GP-C8	Fluid Dynamics	PHYS 314 or MECH 280	
	GP-C9	Fluid Flow Porous Media	EOSC 429	
	GP-C10	Geostatistics	MINE 420	

	GP-C11	Integral Transforms	Some MATH courses may apply.	
	GP-C12	Linear Algebra	**MATH 221**, 223, 307 or 412	MATH 221
	GP-C13	Mathematical Physics	PHYS 312	
	GP-C14	Numerical Methods or Computing	ATSC 409, **EOSC 410**, PHYS 210, 410, MATH 210, 360, 405 or 406	EOSC 410
	GP-C15	Optics	PHYS 408, 458	
	GP-C16	Partial Differential Equations	MATH 257, **316**, 400 or PHYS 312	(see GEOPH calendar)
	GP-C17	Signal Analysis	EOSC 354	NA
	GP-C18	Vector and Tensor Analysis	**EOSC 250**, ATSC 409 or **MATH 317**.	EOSC 250
Commun-ication	GP-C19	Thesis	EOSC 449[2]	
	GP-C20	Technical Writing	ENGL 301, SCIE 113 or 300	(see GEOPH calendar)
Earth & Planetary Geoscience	GP-C21	Geomagnetism or Paleomagnetism	No equivalent UBC course	
	GP-C22	Global Tectonics	EOSC 332	
	GP-C23	Global Geophysics	**EOSC 212**, 453	(EOSC 212)
Field	GP-C24	Field Techniques	EOSC 223, 328 or 429	
Fundam'l Math or Physics	GP-C25	Complex Analysis	MATH 305 or 440	
	GP-C26	Differential Equations	**MATH 215**, 255, 256, 257, 316 or 400	(see GEOPH calendar)
	GP-C27	Electricity & Magnetism	PHYS 301	
	GP-C28	Mechanics	PHYS 170, 216, 306 or 350	
	GP-C29	Thermodynamics	**PHYS 203, CHEM 205** or CHEM 304	(see GEOPH calendar)
	GP-C29	Vibration, Waves & Optics	PHYS 318 or 408	
Geology	GP-C30	Geochemistry	EOSC 333	
	GP-C31	Igneous Petrology	EOSC 321	
	GP-C32	Metamorphic Petrology	EOSC 322	
	GP-C33	Sedimentary Petrology	EOSC 320 or 421	
	GP-C34	Structural Geology	EOSC 323 or 422	NA
	GP-C35	Tectonics	EOSC 332	
Geophysical Methods & Interp'n	GP-C36	Analytical Methods	ATSC 409, EOSC 454	(EOSC 454)
	GP-C37	Marine Geophysics	No equivalent UBC course	NA
	GP-C38	Electrical & EM Methods	EOSC 350	NA
	GP-C39	Gravity & Magnetics	EOSC 450	NA
	GP-C40	Seismology	EOSC 353	NA
	GP-C41	Radiometrics	No equivalent UBC course	
	GP-C42	Rock Properties or Rock Physics	No equivalent UBC course	
	GP-C43	Seismic Interpretation	EOSC 353	NA
Modern Physics	GP-C44	Modern Physics	PHYS 250, 330	

2 EOSC 449, Honor's Thesis, is a 6 credit course. 3 credits count towards a writing credit. 3 additional credits can count towards a topic specific credit with a supporting letter from the supervisor nominating the topic category.

Near Surface Geoscience	GP-C45	Environmental Geophysics	EOSC 350	NA
	GP-C46	Geomorphology	EOSC 330, GEOS 206, 405 or 406	
	GP-C47	Geographic Information Systems	**GEOS 270** or 370	
	GP-C48	Glacial or Quaternary Geology	GEOS 408	
	GP-C49	Remote Sensing	GEOS 373 or ATSC 301	(ATSC 301)
Regional Geology	GP-C50	Geology of Canada	No equivalent UBC course	
	GP-C51	Geology of North America	EOSC 332	
Resource Geoscience	GP-C52	Fluid Flow in Porous Media	Grad courses only	
	GP-C53	Hydrogeology/ Hydrology	EOSC 325, **329**, 428 or GEOS 305	
	GP-C54	Mineral Deposits Geology	**EOSC 331**, 424	
	GP-C55	Petroleum Geology	EOSC 432	
	GP-C56	Reservoir Engineering	No equivalent UBC course	
	GP-C57	Well Log Analysis	Part of EOSC 432	

Other relevant geophysics courses

Have you taken other courses that you think are relevant – including graduate level courses - but do not fit into any of the categories above? If so, for each relevant course, please provide a course syllabus, and write a brief explanation of how the course is relevant to the profession of geoscience in geophysics.

Subject	(Institution Name) Course	How relevant to professional geophysics

Requirements for BSc in geophysics

Aug, 2023 - preliminary version.

All requirements here are for BSc Majors in Geophysics.

Details vary for honours, combined and other degree options.

						Faculty of Science requirements - credits					
Courses for UBC BSc Majors in Geophysics.	**credits**	**term**	**recommend for EGBC**	**EGBC course Number**	**Course(s) taken** (student's list)	**Sci Breadth**	**3/4xx**	**Science**	**3/4xx Sci**	**Arts**	**Not Arts or Sci**
minimum credits	*120*			*Coloured to*		*18*	*48*	*72*	*30*	*12*	*24 (MAX)*
Credits taken	*120*			*help count*		*18*	*48*	*95*	*36*	*12*	*0*
First Year											
Communication Requirement	3	1		GP-C20							
CHEM 121 (or 111 or 141)	4	1		FS-A3				4			
CHEM 123	4	2		COM-B2		3		4			
MATH 100 or 102 or 104 (or 120 or 180 or 184)	3	1		FS A1				3			
MATH 101 or 103 or 105 (or 121)	3	2		COM-B1		3		3			
PHYS 106 or 107 or 117 (or 101 or 131)	3	1		FAS-A3		3		3			
PHYS 108 (or 118)	3	2		COM-B3				3			
PHYS 119 (or 109)	1	2						1			
DSCI 100	3	1		COM-B6		3		3			
Elective	3	2								3	
Total 1st year Credits	**30**										
Second Year											
Communication Requirement	3										
EOSC 212 or (EOSC 111 and one of EOSC 110, 112, 11	3		EOSC 212	GP-C23				2			
EOSC 211	3			COM-B5		3		3			
EOSC 250	3			GP-C18				3			
MATH 200	3			GP-C1				3			
MATH 215	3			GP-C26				3			
MATH 221	3			GP-C12				3			
CHEM 205 or PHYS 203 (thermo)	3			GP-C29				3			
Elective	3		EOSC 220	COM-A1				3			
Elective	3		EOSC 221	req'd for 323				3			
extra 2nd yr course needed for EGBC	*3*		*EOSC 223*	*COM-A4*				3			
Total 2nd year Credits	**33**										
Third and Fourth Years											
EOSC 352	3			GP-C4			3	3	3		
EOSC 354	3			FGP-A1			3	3	3		
EOSC 410	3			GP-C14			3	3	3		
EOSC 453	3			FGP-A2			3	3	3		
MATH 316 (or PHYS 312)	3			GP-C16			3	3	3		
MATH 317	3						3	3	3		
Three of EOSC 329, 353, 450, 429, ATSC 404 **or (two of** EOSC 329, 353, 450, 429, ATSC 404) **and one of** EOSC 350, PHYS 301, MATH 345)	3		EOSC 353	FGP-A3			3	3	3		
The second of the EOAS courses as above	3		EOSC 450	FGP-A5			3	3	3		
The third of the EOAS courses as above	3		EOSC 350	FGP-A4			3	3	3		
Elective	3		EOSC 454	GP-C36			3	3	3		
Elective	3		EOSC 222	COM-A2				3			
Elective	3		EOSC 323	COM-A3			3	3	3		
Elective	3		EOSC 329 or 33	GP-53 or 54			3	3	3		
Elective	3		BIOL or CPSC	COM-B4		3	3	3			
Elective	3		arts							3	
Elective	3		arts							3	
Elective	3		arts 3/4xx				3			3	
Elective	3		3/4xx				3				
Elective	3		3/4xx				3				
Elective *(not needed if EOSC 223 is counted to total)*											
Total 3rd and 4th year Credits	**57**										

NOTES:

This table for BSc Majors degree only. For Honours, combined majors and other options see the link in the next note.

All UBC geophysics degree requirements are detailed at https://vancouver.calendar.ubc.ca/faculties-colleges-and-schools/faculty-science/bachelor-science/geophysics

FoS requirements are at: https://vancouver.calendar.ubc.ca/faculties-colleges-and-schools/faculty-science/bachelor-science/general-degree-requirements

FoS Communication requirement: SCIE 113 is recommended for year 1

FoS Science Breadth requirement: Only 5 of the 6 requirements are automatically filled. Students need either a BIOL or CPSC elective course.

See FoS science breadth details at: https://vancouver.calendar.ubc.ca/faculties-colleges-and-schools/faculty-science/bachelor-science/science-breadth-requirement

FoS 12 Arts credits requirement: Suggestion is 1 in year 1, then 3 in years 3 & 4, at least one of which is a 3/4xx level course.

FoS 48 credits of 3/4xx courses: necessity for **four** 2xx geology courses means students must ensure electives are chosen to achieve this.

EOSC 454: Available starting 2023W.

EOSC 350: not 'required' for UBC's BSc in Geophysics, but certainly important for professional registration as a geophysicist. **EOSC 454** can serve that role. NOTE: EGBC **requires either** "exploration geophysics" **or** "EM/DC methods" (FGP-A4, FGP-A6 in EGBC's "Group 2B" course list).

EGBC geology requirements: four geology courses (Group: 2A – Compulsory Geoscience), but **five** are "forced" because EOSC 323 requires 223, 222, & 221 which requires 220.

EGBC field course requirement: EOSC 223 is required - UNLESS student gains field experience with instruction elsewhere (coop, summer jobs, research or other). This adds a 6th course to term 2 of year 2. Therefore students could have one less elective in 3rd / 4th year. **NOTE: students should take all EOSC 223 prerequisites in year 2.**

EGBC Group 2C - Other Geophysics: 9 required, 12 options are part of UBC Geophysics required or elective course list.

Geophysics scholarship information

These are some of the geophysics scholarships accessible to undergraduate and graduate students in Canada. Some are for students in specific provinces, some are available to any student in Canada, and a few are accessible more broadly.
NOTE: This is likely an incomplete list. It was complied by F. Jones and BCGS is **not** responsible for the information. Please contact fjones@eoas.ubc.ca if you find errors or omissions. Last checked November 2022.

Red dates are intentionally vague – please check the organizations websites for precise open/close application dates.

Terminology is loose, but **scholarships** are usually merit-based, **bursaries** are usually assessed based on unmet financial need, and **prizes** are given to recognize performance in a particular course, programme, research performance, publication record, etc.

National or beyond

1) **KEGS Foundation**, http://www.kegsfoundation.org/, coordinates many scholarships and bursaries for **undergrad** or **graduate** students pursuing qualifications in **geophysics** in **Canadian** universities and colleges. KEGS is the Canadian Exploration Geophysical Society; https://www.kegsonline.org/
    a. *Submission deadline*: **usually March or April**.
    b. See the "Scholarship Applications" page at http://kegsfoundation.org/application.html
    c. At least 7 named endowed scholarships: see http://kegsfoundation.org/sponsors.html

2) CSEG Foundation is the registered charitable arm of the Canadian Society of Exploration Geophysicists (CSEG). They engage in mentoring, outreach to students, travel grants, scholarships and more; check their homepage. **Graduate, undergraduate or college** students may apply for scholarships so long as they are pursuing degrees in a Canadian institution leading to a geophysics career in industry, consulting, teaching, or research.
    a. *University scholarship* submissions: usually **Sept 1 through Nov. 1** (but check website.)
    b. *University **entrance** scholarship* submissions: usually **April 15 through June 15**.
    c. Scholarships available are listed at https://cseg.ca/foundation/scholarships/ .

3) SEG is the Society of Exploration Geophysicists, based in Houston, Texas but international in scope. Covers all of applied geophysics (hydrogeology, mining, engineering, etc.) although with a significant emphasis on hydrocarbon industries.
    a. *University scholarship* submissions: open **late fall through spring** (check website.)
    b. Their scholarships page is at https://seg.org/Scholarships

4) American Geophysical Union. "AGU supports 130,000 enthusiasts to experts worldwide in Earth and space sciences".
    a. GSSI student grant for near-surface geophysics.
    b. AGU student awards more generally – mostly aimed at "outstanding presentations" at AGU meetings.

5) Search for "**geophysics**" at https://www.scholarshipscanada.com (requires login, but account is free) yields 44 scholarships totalling $76,700+ targeting specific universities. However, most are for Alberta universities.

6) At **Canadian-universities.net**: Go to their **geophysics** page for relevant awards, bursaries, prizes and scholarships in BC.

7) **Young Mining Professionals** Scholarship Fund is at http://www.ympscholarships.com/. It may seem peripheral to geophysics, but efficient, sustainable mining practices need geophysical capabilities. One example is the $10,000 B2Gold UBC scholarship for "*…a student enrolled in an undergraduate Geology, Geological Engineering or Exploration-related program at the University of British Columbia…*". YMPS awards roughly $125,000 each year.

8) **From Geothermal Canada:** For students enrolled in a geothermal studies program at a Canadian institution, we are offering two scholarships:
    a. Geothermal Canada Student Scholarship
    b. Geothermal Canada Student Conference Support

9) The **Frank Arnott - Next Generation Explorers Award** (NGEA™) "*is an international competition where teams of mineral geoscience university students collaborate and innovate to transform geoscience data sets into their interpretation of the subsurface geology and mineralisation targets. Its aim is to build a sustainable supply of enthusiastic, skilled geoscientists that can steer the mineral industry going forward.*" Open to students currently enrolled in an undergraduate earth science degree or post-graduate research (masters or PhD). Teams are encouraged to be multi-disciplinary and include members from other fields of study such as engineers, data scientists, economists, social scientists, etc..

10) Several awards and scholarships listed by the **Council of Chairs of Canadian Earth Science Departments** (CCCESD).

British Columbia

1) **BCGS Industry Internship** awards; Eligibility: **Post-graduate** students, **recent graduates (<3 years) and undergraduates**, from or *currently residing in British Columbia*.
   a. This program aims to bridge the gap between academics and job experiences by facilitating a summer job placement for a geoscience or geological engineering student, with an interest in geophysics. See http://www.bcgsonline.org/scholarship-bcgs-industry-internship/ .
   b. *Submission deadline*: **spring** (check their website).

2) **BC Geophysical Society (BCGS) scholarship** – administered by the KEGS Foundation (see above). History of recipients is listed at http://www.bcgsonline.org/scholarship-kegs-foundation/ .

3) Engineers & Geoscientists British Columbia (EGBC) scholarships: Explore the 9 awards, bursaries or scholarships for undergraduates, 2 types of postsecondary entrance or transfer scholarships, and 7 bursaries or scholarships accessible to undergrads or grad students.

Awards at UBC and the Dep't of Earth, Ocean and Atmospheric Sciences - EOAS.

- **EOAS undergrad awards info** at https://www.eoas.ubc.ca/undergrad/awards-scholarships-jobs
- **EOAS graduate student awards info** at https://www.eoas.ubc.ca/grads/awards-scholarships.
- **UBC undergrad awards info** at https://students.ubc.ca/enrolment/finances/awards-scholarships-bursaries.
   - The section **"Awards for specific student groups"** includes awards for indigenous students, women, students participating in Go Global, and other special groups.
   - **UBC award search filtered** by: Vancouver; Faculty of Science; EOAS; Undergraduate: Result is **37 scholarships, awards or prizes** ALL automatically considered – i.e. no application necessary. Go to https://students.ubc.ca/enrolment/finances/award-search and use filters there to refine the search.
   - The **External awards** page has pointers to third party scholarship and awards aggregators: https://students.ubc.ca/enrolment/finances/awards-scholarships-bursaries/external-awards .
     See especially the **List of external awards** section of this page.
- **UBC info: undergrad** loans, bursaries, & financial support: https://you.ubc.ca/financial-planning/loans-bursaries/
- **UBC info: graduate** scholarships & funding: https://www.grad.ubc.ca/scholarships-awards-funding

Awards at other institutions

Please contact your program advisors.

(Dated:230918)

Geoscience Knowledge and Experience Requirements for Professional Registration in Canada

The tables below contain only the **geophysics** column from the GC-Knowledge document, plus a new column for EOAS courses from the geophysics degree requirements in UBC's calendar.

Table 1:1A - Compulsory Foundation Science
1B - Additional Foundation Science
Table 2:2A - Compulsory Foundation **Geo**science
2B - Additional Foundation **Geo**science
Table 3:2C - Other **Geo**science/Science

Regarding "EU's": The fundamental unit of geoscience knowledge used in the tables in Section 3.3 is the Educational Unit or "EU." **One EU is defined as formal instruction equivalent to a one-semester (minimum 12 weeks' duration) course** in a typical Bachelor of Science or Baccalaureate Degree (B.Sc.) in Geoscience at a Canadian university. For example, one EU could consist of three hours of lectures or equivalent per week, with or without a lab component, for at least 12 weeks. An EU can be considered to be the equivalent of one three-credit-hour course in a 120-credit hour, four-year degree program. The EU, as used here, does not address the manner in which material in each study area is presented in a university program. Its purpose is to provide a quantitative statement about the amount of geoscience instruction expected in each required unit of study.

NOTE from page2: "*It must be emphasized that this document is a summary only and that requirements for registration are set out under the legislative act in each province or territory. Therefore, it cannot cover all aspects of registration in depth, nor does it describe differences in requirements that may exist.*"

Which checklist? How does EGBC apply these for registration in British Columbia? See the "guidelines for completing checklists" document. It say (second bullet pg 1) "***If you are applying in Geophysics**, have attended a post-secondary institution outside of BC, or completed your education at a BC institution that does not have a course equivalency list, **please use a general checklist listed under the "General Self-Evaluation Checklists" section**.*". Therefore, it appears as if the 2011 doc may still be applicable.

Table 1: Groups: 1A - Compulsory Foundation Science and 1B - Additional Foundation Science.

	Groups	Geophysics	EOAS / UBC
1A	**Compulsory Foundation Science*** *(Total 3 EUs - One EU in each area required)* Mathematics, Physics and Chemistry are the foundation sciences on which the principles and processes of geoscience are founded. A strong foundation in these sciences provides the grounding necessary to understand and apply geoscience concepts.	Chemistry Mathematics Physics	
1B	**1B Additional Foundation Science*** *(Total 6 EUs; 6 EUs required, no more than 2 EUs in any one of the six subject areas.)* A strong background in a range of sciences allows the geoscientist to understand how the geosphere interacts with other parts of our world, to communicate and interact with scientists from other	Biology Chemistry Computer Programming Mathematics Physics Statistics	

	disciplines and with other professionals, and to adapt to the many challenges encountered in practice. Subject areas containing the foundational topics listed in the linked descriptors may be substituted - e.g. Geostatistics for Statistics, Biochemistry for Biology or Chemistry. * Biology is highly recommended for those in the Environmental Geoscience stream		
	* NOTE – Requirements in this table must be met by EUs at a first year or higher university level course acceptable for credit towards a degree in science, applied science or engineering. Remedial secondary school level courses, such as algebra, chemistry, geometry, physics or trigonometry are not accepted.		

Table 2: Groups 2A - Compulsory Foundation Geoscience and 2B - Additional Foundation Geoscience.

	Groups	Geophysics	EOAS / UBC
2A	**Compulsory Foundation Geoscience** *(Total 4EUs) (1 EU in each area required).* All geoscientists share common core knowledge around which the profession of geoscience is practiced. These subject areas define the common knowledge base in geoscience required to practice in all three streams of geoscience.	Field Techniques ________________ Mineralogy and Petrology ________________ Sedimentation and Stratigraphy ________________ Structural Geology	
2B	**Additional Foundation Geoscience** *(Total 5 EUs) (Total 5 EUs; Geology and Environmental Geoscience require at least 1 and at most 2 EUs from each sub-group (horizontal lines separate sub-groups), but no more than one in each subject; Geophysics requires 1 EU from 5 of the sub-groups.)* Beyond common foundation science and geoscience knowledge documented above, training in geoscience generally falls into three broad specializations or streams (geology, environmental geoscience and geophysics), that reflect the basis of three broad sub-disciplines of practice in the profession. Each of these sub-disciplines requires a different set of foundational geoscience knowledge.	Digital Signal Processing ________________ Global Geophysics / Physics of the Earth ________________ Seismology/Seismic Methods ________________ Exploration Geophysics ________________ Radiometrics/Gravity & Magnetics ________________ Electrical & Electromagnetic Methods GEOSCIENCE	

Table 3: Groups 2C - Other Geoscience (NOTE: These lists are not meant to be exhaustive)

	Groups	**Geophysics**	**EOAS / UBC**
2c	**Other Geoscience/Science** *(Minimum Total 9 EUs)* *(9 EUs must be at a second level or higher acceptable for science credit toward a degree in science, applied science or engineering and relevant to geoscience).* Extra courses not used in 2A and 2B can be used in 2C. Advanced courses in these topics can also be used. No one single EU	Within each subject area are listed possible courses that could be used to satisfy the geoscience knowledge requirements. EUs must be chosen from at least **4 of the boldfaced subject areas** below. **Applied Math/ Physics** - Calculus - Computer-Controlled Instrumentation - Condensed Matter Physics - Continuum Mechanics - Digital Signal Processing	

	course can be used to cover more than one requirement. The three broad streams of specialization in geoscience (geology, environmental geoscience and geophysics) embrace distinct knowledge sets that are important to geoscientists in each stream, and collectively comprise the particular knowledge base necessary for proper and appropriate practice.	- Electromagnetic Theory - Electronics for Scientists - Fluid Dynamics - Fluid Flow Porous Media - Geostatistics - Integral Transforms - Linear Algebra - Mathematical Physics - Numerical Methods/Computing - Optics - Partial Differential Equations - Signal Analysis - Vector and Tensor Analysis **Communication** - Thesis - Technical Writing **Earth & Planetary Geoscience** - Geomagnetism / Paleomagnetism - Global Tectonics - Global Geophysics **Field Techniques** **Fundamental Math/Physics** - Complex Analysis - Differential Equations - Electricity & Magnetism - Mechanics - Thermodynamics - Vibrations, Waves & Optics **Geology** - Geochemistry - Igneous Petrology - Metamorphic Petrology - Sedimentary Petrology - Structural Geology - Tectonics **Geophysical Methods & Interpretation** - Analytical Methods - Marine Geophysics - Electrical and Electromagnetic Methods - Gravity & Magnetics - Seismology - Radiometrics - Rock Properties/Rock Physics - Seismic Interpretation **Modern Physics** **Near Surface Geoscience** - Environmental Geophysics - Geomorphology - Geographic Information Systems - Glacial/Quaternary Geology	

		- Remote Sensing **Regional Geology** - Geology of Canada - Geology of North America **Resource Geoscience** - Fluid Flow in Porous Media - Hydrogeology / Hydrology - Mineral Deposits Geology - Petroleum Geology - Reservoir Engineering - Well Log Analysis	

Ch.4, **Geoscience Practice Experience** Requirement

From page 10: "*Geoscience graduates need supervised practice experience working in the capacity of a geoscientist to obtain the necessary range of capabilities required to enter independent practice. Individuals preparing to practice independently must have worked in the capacity of a geoscientist both at sufficient depth and over sufficient breadth to become aware of the responsibilities and accountabilities associated with professional practice, as well as to gain the ability to recognize their own limitations as a practitioner.*" Etc …

What's already done for EOAS engineers and geologists?

- Not much in guidelines for geologists, 2022:
- Geol eng guidelines for 2022-23 are more complete but still do not explicitly relate courses to EGBC requirements.

Capstone Courses and Projects – An Overview

Dr. Carrie Hunter, curriculum consultant, CTLT. August 8, 2022.

Contents

Definition

A capstone occurs at the end of a course or program and allows students to demonstrate that they can apply and integrate prior learning in new and more advanced ways. It involves "culminating experiences in a course or program, in which students are given opportunity to synthesize prior learning and demonstrate their readiness for graduation" (Lee and Loton, 2019, p. 134). Similarly, Rowles et al. describe it as a culminating set of experiences that "captivate, encapsulate, synthesize, and demonstrate learning." The plan, processes and products involve student independence and responsibility and are unique for each student or student team.

Types

The style, scope and scale of capstone experiences in Higher Education "…vary considerably, resulting in significant differences in student learning experiences and outcomes." (Lee, N. and Loton, D., 2019, p. 134). They may take on the form of

- real or simulated work experiences (e.g. work placement, internship, community-based learning, community/industry partnership project),
- research opportunities (various forms of delivery)
- design and build projects,
- a synthesis essay or report,
- an analysis and reporting (variety of forms) using data not seen before,
- or any number of other forms.

They may be individual or group based. They may be one experience within a course, or more commonly, a "course" unto themselves, lasting 1 or 2 semesters.

Purposes of Capstone Experiences

The purposes reported by faculty responsible for Capstone experiences vary greatly. Every program should clearly define what purpose(s) their capstone should serve and design and evaluate the capstone based on that definition. Lee and Loton (2019) identified 43 purposes for Capstone experiences from the literature and from instructor reports. Each can be classified within the following five categories.

1. Evaluation of Student Achievement and/or Application of Program Knowledge & Skills

The most common purposes are related to student evaluation: testing disciplinary knowledge and skills, specifically, the students' ability to synthesize and integrate knowledge and skills from previous courses with higher order cognitive processing, such as critical analysis (Durel, 1993; Lee and Loton, 2019). According to Young, Chung, Hoffman, & Bronkema (2017), a well-designed capstone course should "*…facilitate the pinnacle of students' ability to engage and demonstrate critical thinking, communication, problem-solving, and team building.*" The opportunity to integrate knowledge and skills opens new pathways in the brain, new connections are formed between learnings, and students are more engaged and more creative. Capstones provide opportunities for more thoughtful student reflection in contrast to traditional assessment and enable students to make sense of their graduate program in a systematic way (Brown and Benson, 2005). Students can start to see the bigger pictures in the discipline, make their own new connections, and ask and answer their own novel questions (Camenga, 2013). As students raise questions of their own rather than merely "receiving" the so-called wisdom of the ages, they take a new and more active role in their own learning" (Brown and Walter, 2005).

2. Affective Pedagogy

Capstones are sometimes tasked with advancing students' attributes, dispositional and personal aspects, such as independence, responsibility, resilience, self-efficacy, diligence and confidence. (Lee and Loton, 2019). McNamara et al. (2011) describe the intention for Capstone experiences to consolidate students' lifelong learning attributes, such as resilience, self-confidence and self-efficacy, enhancing their future professional and personal lives. Schermer and Gray (2012, p. 56) explain that Capstones "*engender self-sufficiency and independence, perseverance and self-understanding….confidence is built through the complexity and scale of capstone activities… students often end [the capstone] confident that they can achieve more than they thought.*"

3. Transferable Skills and Employment Preparation Pedagogy

Increasingly, the literature is identifying that Capstone experiences serve pedagogical purposes of developing heightened capability in students for what are often thought of as transferable skills and employment preparation (Lee and Loton, 2019). These skills include communication, management (including project management), decision-making, creativity, critical thinking, leadership, entrepreneurship, developing a professional identity, and collaborative problem-solving (Keller, Parker, and Chan 2011; McNamara et al. 2012; Schermer and Gray 2012). Many authors cite using real or simulated work experiences as Capstones as a vehicle for providing real-world and professional context experience that will better prepare them to enter the workforce (Kachra and Schnietz 2008; Ryan, Tews, and Washer 2012).

UBC co-op experiences can be treated as Capstone experiences. Several questions worth pursuing further include: are coop experienced assessed as capstone experiences? Is there oversight to ensure that Program Level Learning Outcomes are both articulated and met? Are alternatives to formal coop experiences available and visible to students?

4. Research Pedagogy

When programs anticipate some of their graduates will go on to advanced research studies, they may identify the strengthening of student research capacity as a purpose of their Capstone options for some, if not all their students (Hauhart and Grahe 2012; Schermer and Gray 2012).

There are many benefits of undergraduate research experiences, with plenty of literature on the issue; Google "Research Experiences for Undergraduates" or REU. For example, the National Science Foundation includes a whole category of funding opportunities in the USA to promote and encourage REU (https://www.nsf.gov/crssprgm/reu/).

5. Program Evaluation and Quality Assurance

Increasingly, Capstone experiences are being designed to serve as data sources for program evaluation and quality assurance. Student achievement can be benchmarked and audit activities can be designed (Group of Eight 2014; Krause et al. 2014).

Benefits of Capstone Experiences

Participating in capstone experiences have been linked to engagement in deep learning and gains in personal and social development, practical competence, and general education (Young, Chung, Hoffman, & Bronkema, 2017). Each of the purposes listed above can be thought of as a benefit. To summarize, Capstone experiences can:

- Develop in the students a heightened capacity to apply and integrate previous learning in complex and novel ways.
- Help students to improve various attributes and dispositions such as resilience, confidence and independence that will serve them in their personal and professional lives.
- Improve students' transferable and employment skills such as team work, communication, leadership and problem-solving.
- Develop students' research abilities. Associated skills and experiences are beneficial for all future occupations, and (of course) are important for those students hoping to engage in more advanced research studies after graduating.
- Provide data for program evaluation and quality assurance and improvement.
- Anecdotally, capstone experiences are also important for enhancing motivation, both before and during capstone activities. Instructors invariably remark on how much more focused and energetic students become when tackling a meaning project with peers.

Keys for Effective Capstone Experiences

The University of Hawaii (n.d.) suggests several keys to effective Capstone experiences, including:

- Students demonstrate mastery and integration of previous learning, instead of learning new content knowledge and skills
- Student ownership, responsibility and engagement is central
- The learning outcomes of the Capstone should be defined based on the program/discipline needs and (ideally) fitted to specific needs/contexts of each student. Capstones experiences are less about gaining new skills or knowledge and more about applying, creating, or synthesizing.
- Student evaluation should be based on their ability to meet the Learning Outcomes, assuming these outcomes articulate the criteria that characterize and optimal capstone "product".
- Satisfactory completion of the Capstone should be a requirement for graduation.
- Full time, experienced faculty should facilitate, mentor and coordinate the Capstone.

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Ryan, M. D., Tews, N. M., and Washer, B. A. (**2012**). *Team-teaching a Digital Senior Capstone Project in CTE.* Techniques: Connecting Education and Careers 87 (2): 52–55.

Schermer, T., and Gray, S. (**2012**). *The senior capstone: Transformative experiences in the liberal arts.* Final report to the Teagle Foundation.

Ryan, M. D., Tews, N. M., and Washer, B. A. (**2012**). *Team-teaching a Digital Senior Capstone Project in CTE.* Techniques: Connecting Education and Careers 87 (2): 52–55.

The University of Hawaii (n.d.) Develop a Capstone, available at https://manoa.hawaii.edu/assessment/resources/capstone-experiences/

Young, D. G., Chung, J. K., Hoffman, D. E., & Bronkema, R. (**2017**). *2016 National Survey of Senior Capstone Experiences: Expanding our understanding of culminating experiences* (Research Report No. 8). Columbia, SC: U. of S. Carolina, National Resource Center for The First-Year Experience & Students in Transition.

Career Learning in Courses

Geophysics or Math

NOTE – FJ added these to Zotero reference library May 30, 2022.

Literature Review

Review literature to identify current examples where **career development is embedded within undergraduate quantitative or interdisciplinary sciences** such as: geophysics, atmospheric sciences, oceanography, math, physics, or data science.

Methods

The following description is a high-level overview of the methods and practices used to review existing teaching and learning literature for intersections with career development.

Inclusion Criteria

- Initially (May 27, 2022) - Geophysics, Math teaching and learning literature
- Not yet included - Atmospheric Sciences, Physics, Statistics/Data Science, Oceanography
- Peer-reviewed
- Scholarly articles
- Scholarly periodicals or association publications
- Last five years

Exclusion Criteria

- Non-science teaching and learning literature
- Publications in languages other than English

A framework for *HOW* career is embedded in a degree experience:

1. **Professional preparation** - activities, lectures, or assignments where students learn about their strengths, write personal philosophy statements, listen to alumni guest speakers, or practice career management skills (resume writing, interviewing, or researching labour market data).
2. **Discipline-specific experiences** - students gain credit for discipline-specific experiential learning like research projects, community-based experiential learning, internships, practicums, co-ops, field school, international study, etc.
3. **Pedagogies and course-design** - students develop future work competencies – like complex problem solving or communication – as a result of activities like presentations, team assignments, real-world case studies, ePortfolios, etc.
4. **Applied learning** - Capstones or applied research projects create opportunities for students to integrate learning from multiple sources or experiences and/or apply theoretical learning to real-world problems.

Browsing

UBC library page

Review journals by subject

The following Journals were identified as relevant sources for potential literature. Consistent search term "career" were used to ensure comprehensive and broad results rather than emphasizing topics like "job search" or "career-readiness" or even "career development".

1. PRIMUS: Problems, Resources, and Issues in Mathematics Undergraduate Studies
2. International Journal of Mathematical Education in Science and Technology
3. Research in Mathematics Education
4. Mathematics and Computer Education
5. Numeracy : advancing education in quantitative literacy
6. Teaching of Mathematics
7. ZDM
8. Mathematical Thinking and Learning
9. Mathematics Education Research Journal
10. Teaching Mathematics and its Applications
11. Physics Education (date range: last 5 years)
12. IOP Science (multiple journals) (date range: last 5 years)

Results

Annotated Bibliography

Based on search results from April 22, 2022 to May 20, 2022. Items marked * are in FJ's Zotero.

Abramovich, S., & Grinshpan, A. Z. (2008)*. Teaching mathematics to non-mathematics majors through applications. *PRIMUS Problems, Resources, and Issues in Mathematics Undergraduate Studies*, *18*(5), 411–428. https://doi.org/10.1080/10511970601182772

This article focuses on the important role of applications in teaching mathematics to students with career paths other than mathematics.

Andrew Hirst, & Veronica Benson. (2021)*. Advice for post-COVID careers. *Physics World*, *34*(11), 54–55. https://iopscience.iop.org/article/10.1088/2058-7058/34/11/43

Magazine article providing field-specific career messaging in light of evolving skills expected by employers following the COVID-19 pandemic. ,". See also the regular Careers column at physicsworld. See also section "Other Options and Ideas" item 6, below.

Ashline, G. (2016)*. Real-World Examples: Developing a Departmental Alumni Network. *PRIMUS Problems, Resources, and Issues in Mathematics Undergraduate Studies*, *27*(6), 598–605. https://doi.org/10.1080/10511970.2016.1234528

Illustrates strategic institutional goals for developing a Math department alumni network, including benefits of such a dynamic, engaging network to students, faculty and alumni.

Atanasov, R., Foguel, T., & Lawson, J. (2013)*. Senior Capstone Seminar: A Comprehensive Learning Experience. *PRIMUS Problems, Resources, and Issues in Mathematics Undergraduate Studies*, *23*(4), 392–402. https://doi.org/10.1080/10511970.2012.748112

Overview of a capstone course where assignments included a resume, math proofs, an article review, and a class presentation. Successes w.r.t. course objectives are discussed. These objectives are:

- Students should exhibit a broad understanding in a range of mathematical areas, encompassing abstraction and formal proof as well as application.
- Students should integrate information from a variety of contexts and sources.
- Students should solve complex problems.

- Students should communicate their mathematical knowledge accurately and effectively, both orally and in writing.
- Students have prepared for a career in the discipline.

Capello, M. A., Shaughnessy, A., & Caslin, E. (Jan. 2021)*. The geophysical sustainability atlas: Mapping geophysics to the un Sustainable Development Goals. *Leading Edge*, *40*(1), 10–24. https://library.seg.org/doi/10.1190/tle40010010.1
FJ favourite article. A powerful link between the 17 U.N. Sustainable Development Goals (sDGs) and field of Geophysics. Clear career application. Detailed, and includes 17 "recommended (web) resources". NOTE: As inspirational content, that this article is is licensed under a Creative Commons Attribution 4.0 International License (CC BY), so any or all can be reproduced, with proper attribution.

Estis, J., & Lewis, D. (2020). View of Improving Mathematics Content Mastery and Enhancing Flexible Problem Solving through Team-Based Inquiry Learning. *Teaching and Learning Inquiry*, *8*(2), 165–183. https://journalhosting.ucalgary.ca/index.php/TLI/article/view/68608/54211
One of many examples of Team or Problem Based Learning in Math. Specific focus on how TBL supports students to **learn workplace competencies** like content mastery, flexibility, problem solving, and communication. Included "standards-based grading", which involves "*assessment based on whether students have mastered the learning objectives (standards) completely or not. Course grades are assigned by counting the number of standards mastered, without regard to when or how (quiz, test, or final exam, for example) the student demonstrated mastery.*"

Jiracek, G. R., Scott Baldridge, W., Biehler, S., Braile, L. W., Ferguson, J. F., Gilpin, B. E., & Alumbaugh, D. L. (2000). SAGE Learning geophysics by immersion. *The Leading Edge*, *19*(9), 986–990. https://doi.org/10.1190/1.1438780 Available do members only.
Description of large-scale, established, field program with multiple institutions, funding agencies, and partnerships with industry. SAGE is still running, and we certainly approve. Maybe we should consider ways of enabling UBC students to participate. See SAGE home page for details. (SAGE is supported by both SEG and AGU.)

Maass, K., & Engeln, K. (2019). Professional development on connections to the world of work in mathematics and science education. *ZDM*, *51*, 967–978. https://doi.org/10.1007/s11858-019-01047-7
Provides a framing of competency, skill, and the invisibility of math within the "world of work" (WoW). Describes an international (13 countries) professional development program for primary and secondary school teachers (not post-secondary) aimed at enabling them to incorporate inquiry-based learning (IBL) into math learning to explicitly address the "world of work". Research focus is on aspects related to the ProD for school teachers rather than on impacts on students or student learning.

Oremland, L. S., & Szabo, C. (2021)*. Preparing Interdisciplinary Problem Solvers: A Project-Based Course Series for the Mathematical/Interdisciplinary Contests in Modeling. *PRIMUS Problems, Resources, and Issues in Mathematics Undergraduate Studies*. https://doi.org/10.1080/10511970.2021.1962460
Describes a 1-credit course designed to prepare employable competencies for students by preparing them for an international math competition. Also a followup 1-credit course involving participation in those competitions. This is an example of the benefits of – and one approach to facilitating – a capstone project-based experiences in STEM.

Rohde Poole, S. B. (2021)*. Designing and Teaching an Undergraduate Mathematical Modeling Course for Mathematics Majors and Minors. *PRIMUS Problems, Resources, and Issues in Mathematics Undergraduate Studies*. https://doi.org/10.1080/10511970.2021.1931995
FJ favourite article. Case history – a comprehensive overview of course design and clear illustration of how intentional choices by instructors helps students to develop transferrable skills and real-world application of knowledge. Good precedent for designing a capstone project-based experience or course.

Other Options and Ideas

1) What **precedent at UBC**? Eg Centre for Community Engaged Learning.
2) For each **course**, ask EOAS teaching faculty which types of activities (Framework above, pg. 1) they include. Could be a survey or a visit or part of an interview. E.g.,
   a) "*How often do students encounter these 4 types of career preparation activities in your course? a) never, b) once, c) 2-4 times, d) 5 or more times.*"
   b) "*Please identify relevant activities in just a few words.*"
3) Ask students the same thing – their **perception** of career-preparation activities they encounter.
4) Do any peer institutions have curricula that are "challenge-based" or that have high-level, persistent contextual threads for learning during the degree programs?
5) Ask SkyLight (Warren Code) or Mathew (Matt) Coles., Education Program Director, UBC Math for discussion about "career preparation" within Quantitative disciplines.
6) Examples and testimonials related to student – industry or community partnerships:
   a) https://wripa.ac.uk/ and organization that brings students and businesses together to foster innovation and retain talent within northern England.
   b) https://www.sepnet.ac.uk/ a a network of nine universities in the South East of England, working together to deliver excellence in physics research, graduate and undergraduate learning and community engagement.
7) Enhance the EOAS "alumni network" – as per Ashline, G. (2016), referenced above.
8) Discuss ways of incorporating a capstone project-based experience (or even a whole course) for QES specializations. The Rohde (2022) article is a good example of benefits, and how to do this.

Notes about QES course dependencies

November 2021

The focus here is on dependencies between courses throughout a degree specialization's requirements. Aspects of curriculum that are **not** addressed here are those related to (a) specific learning goals / topics or (b) needs of employers and interests or priorities of students.

Comments are inspired by observing QES course dependency maps & figures at https://www.eoas.ubc.ca/~quest/.

Some observations from maps

1) EOSC213 is not required by any other in EOAS, and only as "one of" 3, for CIVL417.
2) Two ATSC and two geophysics 4xx courses require no EOAS prerequisites.
3) Why is EOSC354 not prerequisite for EOSC353? (More on eosc353 in **Questions** below.)
4) EOSC410 seems quite restrictive to undergrads (and taken by only ~4-8). See **Questions** below.
5) The "any programming language" for ATSC405, 409 is vague. Is that OK?
6) Anything requiring EOSC211 - should DSCI100 count too? Currently, ATSC313 is the only EOAS course with DSCI100 as a "one-of" prerequisite.
7) At 3rd year level, only ATSC303 and 313 require any computing. Not even EOSC211 or DSCI100 are required.
8) "Corequisites" are only mentioned twice, once for EOSC250 and once for ATSC404.
9) Do EOSC 45x really need no computing?
10) After collapsing "one-of" lists, all courses have fewer than 3 prerequisites EXCEPT eosc410 and 471.

Ideas for improving dependencies among QES courses and prerequisits

1) Have 4xx "specialist" courses include at least some "either or" prerequisites from EOAS? (eg ATSC405, 406 and EOSC450, 453.)
2) Could ATSC303 have more options for computing prerqs? Currently EOSC211 alone is required.
3) EOSC354:
    a) could Calc1 be swapped out in favour of EOSC211 or equivalent? EOSC211 requires Calc1.
    b) Augment physics requirements by adding PHYS153 & PHYS106 to the either/or.
4) Add SCIE001 to any requirements for Calc1 (3 3rd yr courses) or Physics101 (eg EOSC250).
5) Re. ATSC313: augment physics requirement by allowing PHYS153 & 106?
6) Re. ATSC405: augment Diff Eqns requirement by allowing MATH255 or 256?
7) Re. ATSC404: augment Applied Des requirement by allowing MATH257?
8) Re. EOSC410:
    a) augment stats requirement to include STAT201 or 251?
    b) augment cmpsc requirement to include five courses in "pink" box?
9) Re. EOSC471: augment requirement to include five courses in "pink" box?

Questions

1) Is ATSC212 now redundant?
2) EOSC211
    a) Student feedback from Dawson club members, reported to FJ, March 11, 2022: "significant proportion of the class" gets lost very soon and never really "gets it". Peers attempt to support but often without seeing any breakthrough in understanding. Details not conveyed, but dissatisfaction seems fairly widespread.
    b) Geophysics has included DSCI 100 in required courses. Other programs have not. This will give geophysics students a leg-up when they take 211, yet they are likely the students least in need of it. Will this increase the bimodal nature of student success in EOSC 211?
3) EOSC353
    a) Last offered in 2019W? Not in 2020W and not in 2021W
    b) Adjust to attract more than 3-8 students? Offer alternate years?
    c) Offer at 3rd year level?
4) Are ATSC405, 406 "redundant"?
5) Re. EOSC250:
    a) what in MATH200 as coreq is important?

    b) Or - why not make it a prerequisite (or MATH253) like EOSC213?
6) EOSC410 seems quite restrictive to undergrads (and taken by only ~4-8).
    a) Is EOSC212 or ENVR300 necessary if "3rd yr in EOAS is included?
    b) Is that requirement in fact necessary? (Probably – but worth discussing).
    c) Could single requirement of eosc211 be loosened? Especially if CPSC203 and 210 are required.
    d) In fact, are CPSC203 and 210 really required?
7) What to do about lack of applied geophysics for QES students (grad/ugrad)? EOSC350 is at a lower level, but "should" be required for a geophysics degree if there is no replacement for the old EOSC452.