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Alumni Narratives on Computational Geology

(Spring 1997 – Fall 2013)

by

Victor J. Ricchezza

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology
School of Geosciences College of Arts and Sciences University of South Florida

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Dedication

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Abstract

Recent meetings and publications have discussed what geoscience undergraduates should learn for professional success, and among other items, have identified several quantitative skills and habits of mind as being necessary for geoscience students; many of these items are commonly associated with Quantitative Literacy (QL). The Computational Geology course in the geology department has been evolving at USF for 20 years. The course teaches QL in a geologic setting independent of specific core geology topics. This course has long preceded the national acknowledgment of the need for what it teaches within the field. As the first of a series of related studies intended to find the effect and role of this course within the geoscience community, this thesis study begins as a qualitative narrative inquiry of course and program alumni. In the study reported here ten USF Geology alumni from a variety of career paths who took GLY 4866 between 1997 to 2013 underwent semi-structured interviews recounting their memories of the course, discussing the benefits to them of the course in their careers, and outlining their views of what students should gain from this course for professional success.

The interview results illuminate trends that can be usefully grouped by job/career category. Regulators (3) had the shortest overall interview time, remembered the least in terms of specific events from the course, and had limited (but consistent) suggestions for student learning. Their memories and suggestions were also rarely unique. Consultants (3) were the median group in length, and showed overlap in the content of their interviews to regulators, with additional details
added. Academics (4) had the longest interview times, the most detailed memories from the course, and the most suggestions, possibly due to these interviewees using similar methods in their later careers as course instructors. Consultants and academics related large blocks of story text that were unique while also relating common statements.

Narratives from professionally successful alumni were sought to gain greater detail on the likely impact of Computational Geology than surveys are likely to give. The responses of selected, successful alumni were also sought to help refine questions that are to be used later in surveys of a larger sample population of alumni and to a larger national audience of geoscientists regarding their undergraduate programs and how those programs prepared them with quantitative skills. The information that interview subjects provided about the educational needs for successful entry-level geology professionals were shaped into a series of suggestions for course and program improvement. Course and program improvement suggestions and questions for a proposed survey have been assembled both to improve the GLY 4866 offering at USF for broader dissemination and to contribute to broader discussion of strategies for improving the quantitative skills and learning of geoscientists.
Introduction

Quantitative Literacy in the Geosciences

The Association of American Colleges and Universities (AAC&U) defines the term quantitative literacy (or QL) as:

Quantitative Literacy (QL) – also known as Numeracy or Quantitative Reasoning (QR) – is a "habit of mind," competency, and comfort in working with numerical data. Individuals with strong QL skills possess the ability to reason and solve quantitative problems from a wide array of authentic contexts and everyday life situations. They understand and can create sophisticated arguments supported by quantitative evidence and they can clearly communicate those arguments in a variety of formats (using words, tables, graphs, mathematical equations, etc., as appropriate) ¹.

In fact, the AAC&U provides a rubric specific to QL as a priority in undergraduate education, regardless of field (Rhodes 2009). This QL rubric is applied broadly; the AAC&U is not differentiating this rubric for science, technology, engineering, and mathematics (STEM) majors, but rather for all undergraduates from physicists to poets.

¹ AAC&U QL Rubric http://aacu.org/value/rubrics/quantitative-literacy
There is a tendency among those who use the QL terminology to do so interchangeably with the terms *quantitative reasoning* and *numeracy*, but this is not always justified (Vacher 2014); this jumbling of terms can be noted in the AAC&U rubric. Although the AAC&U has defined the QL term, experts, if defining for their own purposes, may disagree somewhat on this definition. The question is therefore logically raised, what is QL (in the detailed sense of the term)? The following quote from “What’s in a Name? A Critical Review of Definitions of Quantitative Literacy, Numeracy, and Quantitative Reasoning” (Karaali, Villafane Hernandez, and Taylor 2016) discusses the origin of the term. “…scholars and educators have used terms such as *numeracy*, *quantitative literacy*, and *quantitative reasoning*, among others, sometimes interchangeably and sometimes paying attention to nuances and distinctions which were not too clear to outsiders.” The paper then attempts to analyze the various usages of the three listed terms (among others) in an attempt to determine the differences between them and find something of an agreeable definition for them. In doing so, the paper defined QL as having four attributes (quoting directly):

Quality of desired outcome: *ability* and *habit of mind* (intermediate to advanced)

Knowledge domain: *data*, *mathematics/mathematical*, *arithmetic/quantitative*, and *logical* (data-arithmetic-mathematics-logic spectrum)

Display of expertise: analyze, appreciate, decide, understand, use (active, reactive)

Context: *citizen, information*, practical *situations* (daily life, work, civic life)
Beyond the definitions of what constitutes quantitative literacy, it can be reasonably inferred that there are different levels of quantitative literacy. In “Levels of Literacy,” William Powell describes several functional levels of literacy and includes ability with numbers and mathematical communication as part of literacy long before the QL terminology entered common usage (Powell 1977). Powell differentiates between five levels: illiteracy (essentially no functional skills), “preliteracy” (the reading and writing skills that might be common to early elementary education before about the third grade, and which may not be permanent if not used), “basic literacy” (functional literacy for common use in society), and “career literacy” (establishing that certain careers require different levels of understanding; a journal editor must understand language to a far greater degree for career success than a forklift operator). It stands to reason that similar levels can be applied to QL. The proficiency required for basic life functionality is different from the QL needed to be a mechanical engineer or organic chemist, or for that matter, a geoscientist.

In 2014, over 200 geoscience faculty from four- and two-year colleges and research universities as well as geoscience industry and professional organization leaders met under National Science Foundation (NSF) funding at the Summit on the Future of Undergraduate Geoscience Education. The summary report for the summit described that the outcome of the gathering was significant progress toward (among other things) “developing a collective community vision toward… curriculum, content, competencies, and skills” (Mosher et al. 2014). A second summit was held in January 2016, focused largely on department chairs, and an ongoing survey has been given
(still live at the time of this writing) to over 450 participants across a variety of career paths in the geosciences.

The summary report of the original summit indicated that participants collectively determined that the following curriculum, content, competencies, and skills – which are relevant to this study – are necessary for undergraduate geoscience students to learn in order to be successful after graduation.

- **Thinking**
  - Critical thinking
  - Readily solve problems (including spatial and temporal – 3D and 4D – interpreting)
  - Possess strong quantitative skills and ability to apply cognate sciences to geoscience problems
  - Integrate data from different sources, understand uncertainty and ambiguity

- **Content/concepts**
  - Manage and analyze large datasets

- **Skills**
  - Engage in two-way communication with scientists and non-scientists
  - Have strong computational skills and ability to manage and analyze large datasets
  - Ability to solve problems in a practical fashion
The results of the survey\(^2\) started after the first summit confirmed these priorities. However, these needs are not news to many in the geoscience education research community, with some slight exceptions. Chief among these – that is, being perhaps somewhat surprising to some geoscience educators – is the “major conclusion of the summit: developing competencies, skills, and conceptual understanding is more important than taking specific courses”. The survey respondents agreed with this statement by a ratio of approximately 3:1, regardless of their occupation. They also largely agreed with the important skills, competencies, and conceptual content that were deemed important by the participants in the first summit.

The Science Education Resource Center (SERC)\(^3\) contains a wide variety of materials and interventions relevant to this subject, including some directly related to and developed from the course that will be discussed below. Among the most currently relevant of these interventions is one entitled “The Math You Need, When You Need It”\(^4\) (Wenner, Burn, and Baer 2011), which was referenced at the most recent summit meeting.


\(^{3}\) SERC [http://serc.carleton.edu/index.html](http://serc.carleton.edu/index.html)

\(^{4}\) The Math You Need, When You Need It, on SERC: [http://serc.carleton.edu/mathyouneed/index.html](http://serc.carleton.edu/mathyouneed/index.html)
The Computational Geology Course at USF

The course Computational Geology (currently GLY 4866, hereafter referred to as “CG”) has been taught to undergraduates in the Geology Department (later the School of Geosciences) at the University of South Florida for twenty years. The course was started in 1996 under the name Math Concepts (GLY 4145), but with essentially the same goal, which is teaching QL in a geological context. The course was originally started by request from a collection of students, and later became a required capstone course after the department faculty determined that the course met the needs of their students. The course was required from approximately 2000 to 2010, when it became part of a sequence of capstone courses that students could select to complete their undergraduate degree.

The syllabus from 1997 states “the purpose is to enhance computational skills and increase mathematical literacy,” as was discussed in detail in “A Course in Geological-Mathematical Problem Solving” (Vacher 2000). Until the spring semester of 2016, the semester-long course was taught once per year by Dr. H.L. “Len” Vacher (hereafter LV), and has undergone a series of evolutionary changes over the 20-year period since its inception. Since this study was undertaken, the course offering has expanded to include two semesters per year, with LV teaching the fall cohort and Dr. Charles Connor teaching in spring, with the first spring course occurring during the writing of this thesis (full disclosure: the author has served as teaching

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5 Listed course sequence on USF School of Geosciences website at the time of this publication: http://hennarot.forest.usf.edu/main/depts/geosci/ug/geology/
assistant – TA – for both LV and CC over the 2015-2016 school year). The course began primarily as a spreadsheet-oriented problem solving course and later became part of an initiative called Spreadsheets Across the Curriculum, or SSAC (Vacher and Lardner 2010, 2011) which expanded these efforts through the use of PowerPoint modules that direct students through the spreadsheet work. It has since evolved to include multiple other methods beyond spreadsheets to solve quantitative geology problems. It should be noted that the SSAC project is listed on SERC,⁶ and was among the first resources shared with participants in the second Summit on the Future of Undergraduate Geoscience Education.⁷

The course has been involved in three National Science Foundation (NSF) funded grants in some capacity. The initial award was grant #0126500,⁸ which funded the initial development of spreadsheet modules (described in detail later in this work) from 2002 to 2004. The second, #0442629,⁹ was for the previously referenced SSAC project, which greatly expanded the scope of the modules from 2005 to 2010. The last of these, #0836566,¹⁰ was for an expansion of the

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⁶ Spreadsheets Across the Curriculum on SERC: http://serc.carleton.edu/sp/ssac_home/index.html

⁷ Blog page of Dr. Laura Guertin, Penn State University, Brandywine, detailing the second Summit http://blogs.agu.org/members/drlauraguertin/

⁸ NSF Grant #0126500 http://nsf.gov/awardsearch/showAward?AWD_ID=0126500&HistoricalAwards=false

⁹ NSF Grant #0442629 http://nsf.gov/awardsearch/showAward?AWD_ID=0442629&HistoricalAwards=false

¹⁰ NSF Grant #0836566 http://nsf.gov/awardsearch/showAward?AWD_ID=0836566&HistoricalAwards=false
SSAC project “Geology of National Parks: Spreadsheets, Quantitative Literacy, and Natural Resources,” and involved modules specific to U.S. National Parks as well as three additional USF faculty members – Rains, McIlrath, and Juster (Vacher et al. 2012).

The original primary method for achievement of the course’s goals – the use of spreadsheets for quantitative problem solving – became quite common by 2003 (Fratesi and Vacher 2005). This thesis is not the first graduate student work based on the course; former course graduate teaching assistant (TA) Dr. Dorien McGee wrote a chapter of her doctoral dissertation on assessment of the Spreadsheets Across the Curriculum project (McGee et al. 2007).

Among the main goals of the course is to improve QL among geology students to produce quantitatively literate geologists. “Students who experience the geosciences quantitatively will be better prepared to make informed decisions about environmental, public, and political policies” (Wenner et al. 2009). With the basic definition of QL having been established, the question at hand becomes “what mathematics is most important for quantitative literacy? Much of the content of the calculus-driven sequence would not be considered effective in achieving quantitative literacy” (Madison 2001). What would be covered in such a course? A review of the fall 2015 syllabus for computational geology included such topics as numbers and number sense, quantities and units, proportions and percentages, estimation and errors, sums and averages, ratios and rates, logarithms and logarithmic scales, circles and angles (including basic trigonometry), modeling functions (linear, logarithmic, exponential, and power functions, and how to express and interpret them graphically), and direction and distance.
Outputs versus Outcomes

This background information leads into the concept of the difference of outputs versus outcomes. According to “Performance Contracting in the Human Services,” the difference is defined by the government. “The Government Performance & Results Act of 1993 (Public Law 103-62) statutorily defines an output as a measure of “activity or effort” and an outcome measure as “the results of a program” as compared to its intended purposes” (Martin 2000). “Outcomes Assessment: Not Synonymous with Inputs and Outputs” further describes a difference between student outcomes, which they describe as institutional in nature, and student learning outcomes. The authors write of student learning outcomes,

As opposed to outcomes that measure aggregated statistics on an institution-wide basis, student learning outcomes are concerned with attributes and abilities, both cognitive and affective, which reflect how the student experiences at the institution supported their development as individuals. (Dugan and Hernon 2002)

This definition fits closely with the goals of computational geology, where achievement of student learning outcomes is prized above other considerations. The primary desired student learning outcome, speaking generally, from the computational geology course is for geology graduates of the program to be quantitatively literate. But how can this be effectively measured? Most determinations made in the course, such as course exams or labs, would qualify as outputs rather than outcomes. However, these outputs can perhaps have some predictor ability on eventual outcomes in the absence of assessments or evaluations that measure that outcome directly. This unresolved question informed part of the reasoning behind this current thesis study.
Personally dissatisfied with student output results from recent semesters, LV undertook a review of Cognitive Load Theory (Chandler and Sweller 1991, Sweller 1988, Sweller, Ayres, and Kalyuga 2011, Sweller, van Merrienboer, and Paas 1998). This review and the subsequent course revisions were done with the intent of streamlining the cognitive load placed on undergraduate geoscience students in solving quantitative problems within the course. That is, the skills and knowledge asked of the students did not change based on this review, per se, but the method of presenting the material did. Cognitive Load Theory is partially based on the seminal work in “The Magical Number Seven” (Miller 1956), which discussed that the human mind has a limited capacity for keeping non-memorized information in ready access (about seven items, plus or minus two). Cognitive Load Theory posits that extraneous cognitive load – extra information the mind must hold in temporary storage – can limit novice learners (students). The course has therefore been subjected to continued redesign to limit unnecessary cognitive load and allow students to concentrate their minds on solving problems. As part of the continued evolution of the course, there have been several changes made, including new hands-on laboratory activities and student problem sets (for homework and study) which were piloted in the fall 2015 semester. However, additional information was sought by the course instructor (LV) to continue to evolve the course in the direction that best fits the needs of the students, the workforce, the school/department, and the field as a whole.

**Long and Short Term Research Projects**

The author of this project has embarked on the study outlined in this thesis as the first of several studies related to, and part of, a long-term project on quantitative literacy in geoscience
education. It is the author’s contention that the Computational Geology course at USF provides a rare opportunity to geology undergraduate students to learn the quantitative skills and habits of mind that successful geologists require, independent of specific core subject classes. Further studies will be undertaken along this line of inquiry involving the outcomes generated by the CG course at USF, the needs of the geoscience education field as a whole, and the intersection of the two.

The study outlined in this thesis has been performed, in part, to collect information directly from course alumni regarding their experiences with the CG course, their post-baccalaureate careers, and their suggestions for student learning experience, and present them as narratives when possible. The study consisted of a series of conversations with ten professionally successful course alumni from a variety of career fields who took the course between spring 1997 and fall 2013. The results from this study will be used to formulate survey questions for a larger (and more representative) population of course alumni, and will be used with Cognitive Load Theory to continue course upgrades. Course enhancements are being made to improve the offering so that graduates who take the course are better suited to be quantitatively literate and prepared for the needs of the career market for geoscientists. This study is envisioned as being part of a larger themed series of projects that help determine the role of QL in the geoscience curriculum (at USF and beyond), and how the needs of the geoscience education community can best be met.

Why begin with a qualitative investigation? For a good reply to this rhetorical question, a reading of “Methodology and Location in the Context of Qualitative Data and Theoretical Frameworks in Geoscience Education Research” (Feig 2011). Feig writes,
Quantitative inquiry can tell a researcher what and how much of something happens, but the question of why is problematic. In pursuit of this line of inquiry, a researcher might find herself awash in information about her students’ attitudes, perceptions, lived experiences, values, and memories. She recognizes these as qualitative data in the form of communicated truths: that is, words, stories, and descriptions, and sometimes nonverbal expressions. These data are not subject to validity tests or manipulation by experiment. In order to extract meaning from these data, the researcher must turn to qualitative inquiry.

**Literature Review of Related Studies**

The CG course is relatively rare, at least in name. A Google search on the term “computational geology” returned information about courses from this institution and two others. This statement, of course, refers to courses which are specifically constructed for the primary purpose of addressing QL within a geoscience context but outside of a specific subtopic of geology; numerous geology courses can be found at most universities with quantitative aspects, but specific to a certain field or subtopic of geology (e.g., a hydrogeology course would almost certainly include quantitative skills). Courses that are very common across many universities in their geology curriculum will be referred to for simplicity in this thesis as “standard geology curriculum” or SGC. SGC courses include such topics as physical geology, mineralogy, petrology, sedimentology and/or stratigraphy, structural geology/tectonics, hydrogeology, volcanology, or seismology. It is not the author’s intent to suggest that this list is complete, or that all universities offer such a sequence of courses exactly, or that some variation cannot be found. It should simply be noted that all of these courses, and several more that could be
included under the SGC umbrella heading are vastly more likely to be taught than computational geology or a similar QL-in-geology course.

However, a targeted course to address QL in the manner of computational geology is not the only way to address the perceived problem; interventions to assist with aspects of QL in the geosciences (e.g., “The Math You Need, When You Need It”) exist outside of the framework of specific classes. In the example given (TMYN), relatively large numbers of students in a physical geology or environmental geology course (>150) used the interventions with percentage-point increases from pre-course test to post-course test ranging from 19 to 42 percentage points. Results were inconclusive when applied to a nearby community college with much smaller course enrollments, possibly due to the statistically unreliable number of students completing the interventions (Wenner, Burn, and Baer 2011). When this intervention was later applied to a larger series of students (more than 3000 students across more than 106 courses), results generally showed gains for students of all achievement levels, with the lower-scoring students on the pre-course test showing the highest gains\(^{11}\).

Studies in the literature that discuss the past of QL-in-geoscience courses (or assess their effectiveness) were not found. However, aspects of the study that was performed were found in other studies that were only peripherally related to the CG course when taken at face value.

\(^{11}\) TMYN Results: [http://serc.carleton.edu/mathyouneed/about/results.html](http://serc.carleton.edu/mathyouneed/about/results.html)
A study of alumni regarding their former participation in an undergraduate intercultural exchange course (Dillon 2012) was performed by the instructor for the stated reason of avoidance of complacency in teaching the same course over an extended period of time (>10 years). Dillon contacted alumni who had graduated from his institution and who had taken the course during the first ten years it was taught. A snowball sampling technique (contacting some people and using them as a source of additional contacts) was used to collect a diverse sample set. Dillon exchanged emails with the former students about their experiences, and then arranged follow-up interviews. Dillon used the constant comparative method (Glaser and Strauss 1967) to analyze his transcripts. “The methodological form of narrative provides a way to interact with former students and capture their perspectives” (although Dillon ends his sentence here with “on intercultural competence,” which was the subject of the former course and the interviews, it seems reasonable that the excerpted portion of the quote is likely true in other contexts.) The Dillon study details a fairly effective method for obtaining information about a course from alumni of that course and using it for the purpose of refining the teaching and learning goals.

An older study of students and alumni at a large Midwestern university (Pearson and Sorenson 1980) focused on the format and requirements of a basic speech communication course. In the study, strictly structured telephone interviews were conducted with a mix of alumni and current students who had taken the existing course. A pilot set of six telephone interviews were conducted to hone the questions in the interview protocol; the revised protocol was read verbatim during the formal interviews. A total of 106 alumni were interviewed, and the assumption would be that an approximately similar number of students would also have been interviewed (actually,
it was noted that students answered their phones and participated in the interviews at a higher rate 89% versus 73% for alumni, so the number of students may be higher). The bulk of the paper is dedicated to specific discussion of the results of the seven questions that were asked in the interviews. The final results indicated that all groups found the course necessary and useful, felt it should be required for all students, and had variations simply over minor differences in class size and number of public speaking requirements.

A recent paper from the Journal of Geoscience Education (Boger, Adams, and Powell 2014) described a course redesign for two required Earth Science courses for science majors and teachers at Brooklyn College. Although the redesign is interesting, the more relevant aspect from this short paper is the course evaluation written in with the redesign. The students of the redesigned courses all participated in surveys (using Likert scales), and six students agreed to participate in a focus group to discuss a semi-structured protocol about the redesign.

A study of alumni from an outreach program for K-12 teachers (Laursen, Thiry, and Liston 2012) collected data from 24 participants using semi-structured interviews (two interviewers) with program alumni regarding the impacts that the program had on their careers. This study is very similar in many respects to the current study at hand, although the course being reviewed is quite different.

In a dissertation from New England College (Watman 2014), the author conducted semi-structured interviews with 25 persons associated with this small college. The narrative study was intended to give a broad but well-defined picture of the identity of the college. It included a wide variety of people including faculty, staff, students/alumni, administrators, and the local
community. This dissertation provided an excellent example of narrative being done for the explicit purpose of ‘telling a story’ which in this case is the story of what New England College is all about. The methodology is similar to that used in this thesis, although on a larger scale.
Study Objectives and Procedures

The rarity of the course when compared to SGCs that are commonly found on most campuses raises some interesting questions.

1. Does the computational geology course offer the potential for an outcome that is either not likely or significantly less likely from more commonly taught geology courses (SGCs)?

2. How does the computational geology course achieve these target outcomes (if they are achieved)?

3. How does this course function in the context of the curricular sequence for geology majors?
   Is it generally taken at the same point in the sequence by most students? Does the course’s place in the geology sequence make a difference for students’ outcomes?

4. If the computational geology course achieves useful outcomes that are not noted in more common courses, or are complementary to the outcomes of those common courses, how can the computational geology course be disseminated to a broader audience?

Of the four questions listed above, the first is only tangentially addressed in this study. The computational geology course at USF was originally built – partially at the request of students needing additional assistance with QL and later at the decision of the faculty – to address and achieve a very specific outcome. Namely, this course was intended to produce (in conjunction with other geology courses) quantitatively literate geologists. This study does not compare computational geology to other courses. However, the study does attempt to determine
(qualitatively) whether the course achieves the desired student learning outcome, and how this achievement was done.

The third question is not directly addressed through this study. An informal conversation with the undergraduate advisor for the geology majors indicated that a relatively large number of USF geology majors are either community college transfers or late major changes. The BS curriculum sequence\textsuperscript{12} is largely set on the assumption that a student majoring in geology is a “first time in college” (FTIC) four-year USF student who makes the decision of major upon entry to the university as a first-year student. As of spring 2016, the advisor reported that 89 of USF’s 152 listed undergraduate geology majors were transfer students, with most of those being community college transfers. This figure doesn’t account for students who came directly to USF but started in a different major. USF policy\textsuperscript{13} strongly discourages exceeding 120 credit hours or taking more than 8 semester as an FTIC student or 60 credit hours and 4 semesters as a community college transfer student. The high number of non-standard students (defining a standard student as a FTIC, four-year, USF student who selects geology as their original major and begins work directly toward that goal upon arrival on campus) within the major indicates that despite the plan

\textsuperscript{12} USF Geology BS curriculum sequence for four-year graduation: \url{http://ugs.usf.edu/eight-semester-plans/?display=plan&progcode=BS-GLS}

\textsuperscript{13} USF undergraduate policy regarding graduation within 8 semester and 120 credit hours: \url{http://regulationspolicies.usf.edu/policies-and-procedures/pdfs/policy-10-505.pdf}
for this course to be in the sequence as a capstone course, this plan is often not the case in practice.

The fourth question – how to disseminate this course to a broader audience – is one reason doing this thesis study and the dissertation study that will follow. The opportunity presented here is truly unique. A rare course has been taught by the same instructor at the same institution for twenty years, and this course appears to have anticipated the needs of the field by a long period of years. The details of the teaching methods may have changed over that time, but the goal outcome has not. To pass up the opportunity to study this situation, at this time, would seem injudicious.

With this information in mind, the most relevant short-term questions became the second: how to determine whether and how the course was effective in achieving the desired outcome. Because the course has been offered for two decades, alumni of the course have had an opportunity to complete degrees – including advanced degrees in some cases – and gain meaningful workforce experience in a variety of professional settings. The simplest method of determining the impact of the course to geology alumni was to sit down and ask them about the course. This thesis is primarily a narrative inquiry – a qualitative study where interviewees are encouraged to tell their stories – with analysis of common threads and unique statements, and the implications of each toward the original questions.

**Methods**

The following practical research questions drove this thesis study:
For alumni who took and passed the course between 1997 and 2013:

1. What was their experience in the course and what memories did they retain?
2. In what ways was the course of practical use to them in their professional or personal lives, post-graduation?
3. What are the needs of the workforce, as expressed by the study population, in terms of what could or should be taught in this course?

Based on these basic research questions, a list of 20 alumni was assembled by LV. Those persons all met the following criteria:

- Took and passed Computational Geology or Math Concepts as undergraduates between 1997 and 2013
- Graduated from USF with a BS in geology
- Went on to professional success – to the knowledge of LV – within their chosen career field
- Collectively covered a spread of private sector/consulting, public sector/regulatory, and academic job roles in approximately equal measure.

From the initial pool of twenty candidates, interviews were scheduled and conducted with ten. In accordance with the USF Institutional Review Board (IRB) approval (e22615), interviews were conducted with informed consent. Participants were granted anonymity through the use of pseudonyms in the interview process, and, to avoid unnecessary bias, interviewees selected their own pseudonyms at the time of the interviews. To protect this anonymity, the consent forms are
not included (as they include the legal names of the participants), but they are on file as required by the IRB, under lock and key, in the office of the author (VR). A copy of the IRB approval is included in Appendix A.

It is important to note a disconnect between the initial research questions, which address the entire population of course alumni, and the population from which the interviewees were drawn. This disconnect is primarily through the third qualification listed above: professional success. Although limiting the interviewees to those who are professionally successful introduces bias and limitations to this study (see the Reflexivity subsection of the Discussion for more details), using a pool of successful alumni allows the study to focus on what aspects of the course were of use to those who went on to successful careers. It is of utmost importance that the professionally successful criterion be explained further. This was not a rigorous or measured definition in any way. Those who were deemed to meet this criterion simply met LV’s personal ideas for professional success as a “yes/no” proposition, and once that was determined, the matter was not considered further. Academics were not judged by whether they had achieved tenure, or how their reviews from students were rated, or how much grant money they brought to their department or school, or how many papers they authored in what journals. Consultants were not judged by number or level of clients, or hourly billing rate, or number (or percentage) of billable hours, or by annual salary, or by bonuses generated. Regulators were not judged by caseload or other criteria, other than that they had succeeded in finding and maintaining employment in the field, and negative commentary within a tightly-knit local community had not been noted. As noted above, this definition is far from rigorous, and furthermore, varied depending on the time
since graduation. Someone who graduated in 1997 would be presumed to have accomplished a
great deal more, professionally, than someone who graduated in 2013. Additionally, LV is not
necessarily aware of the inner workings of regulatory agencies, consulting firms, or academic
departments, and “success” determinations were based only on his knowledge, which is not
presumed to be absolute. Per the Conclusions section, additional studies are recommended from
a broader and more representative study population, and “professional success” may not be
considered in future studies due to the difficulty in determining just what that actually means.

Additionally, the spread of career choices was not universal or random. The regulators all
worked for the same regional agency; this similarity was by chance, and was related to which
potential interviewees responded and were willing and able to participate. The three consultants,
although they worked for different companies, all worked for environmental consulting firms.
They were chosen to represent “private sector geologists,” and environmental consulting is only
one form of work for geologists in the private sector (although it is among the largest within the
area near USF). Other forms of private sector geologist could include geotechnical workers (in
Florida, often the sinkhole risk and mitigation industry), mining geologists, energy/petroleum
geologists, and so on. None of these other professions were selected, as none were among the
initial 20 candidates identified. The academics included four people at various stages of their
education (and teaching), but none were tenured professors. As with the criterion of professional
success, the inclusion of these interviewees as being sufficiently representative of the
public/private/academic work sectors for geologists was not entirely rigorous, but was done for
the purpose of determining if different answers were found from different employment
categories.

Study participants sat with VR for a semi-structured interview. A semi-structured interview is
one where a series of set questions is asked, and follow-up questions are allowed, based on the
responses to the original questions. The interview protocol required that the following three
questions be asked:

1. Please think back to when you took the computational geology course as an
undergraduate at USF. Please tell me what you remember from that course.
2. What, from that course, have you used professionally or personally since graduating?
3. What would you like to see students in computational geology learning that would
help them succeed professionally after graduation?

Follow-up questions were permitted and essentially open-ended, and they constituted the bulk of
the interview time. Interviews were audio recorded, and participants filled out a demographic
information sheet (see Appendix B for completed demographic sheets) after recordings were
completed. After interview recordings were transcribed and checked for errors, the audio
recordings were erased, as voices are identifiable. Although it was the intent of the author to
include interview transcripts with this thesis, after analysis it became apparent that despite the
use of pseudonyms, the identity of the participants was not adequately protected by the
transcripts as they were transcribed. Rather than attempt to redact large swaths of information
from the transcripts themselves, the decision was made to redact as needed from quoted blocks
of text in this thesis, and to hold the transcripts under lock and key. Transcripts are available on request, but the author reserves the right to redact identifying information before release.

Eight of the ten interviews were conducted in person. One participant was located out of state, and another had an extremely busy work schedule that did not permit time to come to the USF campus. Both of these interviews were conducted via Skype video conference, with audio-only recording. Interviews conducted via Skype sent signed copies of their consent forms via email and then orally answered the demographic questions, and the questionnaire was completed by VR using the answers provided by the interviewees.

The interview protocol followed a narrative inquiry framework, which means it was intended to tell the stories of the interviewees (Patton 2015). Questions were selected to be as open-ended as possible and still relate to the overall topic (the CG course and its impacts) as one purpose of the study was to see what unexpected things would be said by those with different life experiences.

In “Narrative Inquiry: A Methodology for Studying Lived Experience,” the author writes

Narrative inquiry is an old practice that may feel new for a variety of reasons. It is a commonplace to note that human beings both live and tell stories about their living. These lived and told stores and talk about those stories are ways we create meaning in our lives as well as ways we enlist each other’s help in building our lives and communities. What does feel new is the emergence of narrative methodologies in social science research. (Clandinin 2006)
Indeed, that last sentence quoted could be even more appropriately applied to studies such as this thesis, which cross the divide between domain science, social science, and education research, and where such methodologies as narrative inquiry are fairly new. Although written from the perspective of communication about science to the public rather than methods of research, in “Earth stories: context and narrative in the communication of popular geoscience”, the authors state, “where Earth science frequently has the edge over other physical sciences is that geology does have an innate capacity to present a human angle” (Stewart and Nield 2013).

In this study, participants were not provided information about the protocol before the interviews other than the name of the study (as “Alumni Narratives on Computational Geology”) and an informed consent form indicating that an interview would take place. There were advantages and disadvantages to having interviewees enter the room “cold” (that is, without having seen the interview script). On the positive side, interviewees could not rehearse answers. The responses they give could be presumed to represent their own responses and views, without time to change their minds or call a friend for assistance. On the other hand, lack of ability to prepare kept some interviewees (generally those who declared themselves to have poor memory) from having lengthy responses to questions, or remembering specific details. More than one respondent stated some variant of wishing they had a copy of their syllabus in front of them or that they knew what questions were coming beforehand.
Interview Results

The interview transcripts were, as discussed before, compared with each other for common words, phrases, and concepts using the constant comparative method (Glaser 1965). This method combines standard ‘coding’ of common phrases and words with analysis of the data as it is processed.

Glaser writes,

The purpose of the constant comparative method of joint coding and analysis is to generate theory more systematically than allowed by the second approach [uncoded qualitative analysis] by using the explicit coding and analysis procedures. At the same time, it does not forestall the development of theory by adhering completely to the first approach [coding] which is designed for provisional testing, not developing, of hypotheses.

In the case of this study, as the interview recordings were heard, transcribed, corrected, and analyzed, certain phrases and words were obvious as being very common amongst two or more interviewees. Individual phrases or words were identified or highlighted as “codes.” Coding can be done using pre-set ideas (a priori) or with codes based on the data itself (grounded theory); because the purpose of this thesis, at least in part, was to tell the narratives of the participants,
codes were chosen using grounded theory based on interviewee responses. This topic is discussed further in the Discussion section.

This results section has been broken down into subsections for each of the three scripted questions from the interview, with common themes for each and then unique statements from individuals. Additionally, it became apparent early in the interview process that the physical structure of the course had changed significantly during the time the course has been offered. The pertinent physical and structural details of the course over time are included as a separate subsection.

**Interviewees**

Luke, Gilda, and Sam (all names are pseudonyms) are currently employed as regulators at a regional governmental agency. Luke has completed an MS degree, and Gilda and Sam are in the process of doing the same.

John Doe, John Smith, and Medusa work as environmental consultants in the private sector for three different companies. John Doe and John Smith completed MS degrees. Medusa completed an MS degree and holds a state-level professional geologist license. Medusa also has past experience working as a regulator, and teaches introductory college courses part-time, and thus, although categorized by her primary occupation, could be considered under any of the career categories in this study (for simplicity she has been considered as a consultant as it is her primary current occupation).
Arya and Sunshine earned MS degrees and are currently completing PhD degrees while teaching. Jam earned an MS degree and is a permanent instructor at the collegiate level. Lee is working toward both her MS and PhD degrees.

Jam served as graduate teaching assistant (TA) for the CG course in graduate school. Arya unofficially served in this capacity as well, and wrote and organized a significant portion of the module and module accessory files. Sunshine was employed by LV (according to her interview) during summers of her MS studies organizing and improving the uniformity of the physical appearance of the modules and spreadsheets.

It should be noted that all but two of the interviewees (Medusa and Lee) did graduate work at USF. USF offers a Master of Science program in geology on two different tracks. One is a ‘standard’ thesis track (this work is presented in partial fulfillment of the requirements thereof) and the other is a professional science track which includes a terminal project. The former is usually a full-time experience and may be funded by the university or an advisor’s grant; the latter is usually worked part-time while the student holds part-time or full-time employment, and although it may or may not be subsidized by the student’s employer, it is generally not funded by the university or department. The experience is different for each track, and the eight interviewees who completed (or are in the process of completing) an MS at USF include a mix of both tracks.
Course Structure Evolution

Although it was not one of the research questions to determine how the course had changed over twenty years, during the first interview (Arya), an unexpected topic came up during conversation about memories of the course. She indicated a major difference between the iteration of the course she took in about 2010 versus those the author has encountered from 2014 to present. Her course exams were taken in Microsoft Excel (current exams are more traditional paper-based exams). This led to immediate follow up questions probing other ways the course might have changed over the years, and this line of inquiry was worked into the follow-up questions for the subsequent interviewees.

Table 1 indicates the course structure elements found in the interviews of two or more participants. Table 1 presents the interviewees in the order they took the course, and indicates in green where they mentioned a certain topic (leaving that area grey if they did not); this format is used in similar tables to follow. The exception to this format was the question of exam format. Unlike the other topics, which were brought up by the interviewees, the topic of exam format was brought up by the interviewer for all interviewees except Arya and Medusa. In the case of Arya, as noted above, she was the first person interviewed, and her unexpected response regarding the exam format was what led to this question being brought up, when appropriate, with the other interviewees. In the case of Medusa (the last person interviewed), the topic did not get addressed, as it did not become an appropriate subject of conversation. Because that topic was brought up, unlike the others, by interviewer probing, a separate yellow-tan color code is used in Table 1 to indicate that the topic was not addressed in Medusa’s case.
Table 1: Common Course Structure Memories

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Computer Lab</th>
<th>Excel</th>
<th>Modules</th>
<th>No TA</th>
<th>Denis TA</th>
<th>Later was TA</th>
<th>Paper Exams</th>
<th>Excel Exam</th>
<th>Mixed Exams</th>
<th>Lecture</th>
<th>Group Problems</th>
<th>Quizzes</th>
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<tbody>
<tr>
<td>Medusa</td>
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<td>Sunshine</td>
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<td>Gilda</td>
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<td>Arya</td>
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<td>John Smith</td>
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<td>John Doe</td>
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<td>Lee</td>
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Key: Item Present | Item Not Present | Topic Not Addressed In Interview

What follows is neither comprehensive nor exhaustive by any means, but does roughly outline some changes noted between approximately 1997 and 2013. Medusa took the course first chronologically among the interviewees (spring 1997), and described a course without a pre-set schedule of topics,

…he walked in and said ‘what’s holding you up? What sort of concepts are you having trouble with? What’s not working for you? Why are you failing calculus? What’s holding you up?’ And we spent the first couple of classes talking about that – what we felt we did and didn’t understand, you know… things for which we didn’t understand the relevance of why they were being presented to us. And he came up with a course description based on that.

She described a course where spreadsheets – then not common in other departmental courses – were used to solve problems. The course involved a relatively high amount of calculus, as students had a lot of trouble with this subject in other courses (calculus is generally only...
discussed conceptually in later versions of the course, although Calculus 1 is a required prerequisite). It is worth considering that the capabilities of the Microsoft Excel suite have changed considerably since 1997; however, while this issue did not come up in the interview, the assumption regarding this skill set would be that any new changes would be learned on-the-job. Medusa mentioned that the spreadsheet skills were immediately useful upon entering the workforce.

Jam took the course in fall 2001, and is the only student to describe the use of a textbook, *Computational Engineering Geology* (Derringh 1998); she also described the use of Excel for problem solving. Homework for the course would consist of both Excel sheets and problems from the text. Class would start with a quiz, which was a homework problem with the numbers replaced. After the quiz, a question or problem would be posed, and group discussion would ensue, which she found frustrating as she didn’t know where to begin. Exams were on paper, but at times required students to explain what they would write in Excel to solve a problem, which Jam also found very frustrating without Excel in front of her to see. She started graduate school the next summer, and spent the summer helping LV write what would become the first of the PowerPoint modules to accompany the spreadsheets and make them more accessible (see Vacher and Lardner, 2005) before serving as TA for a later version of the course.

Sunshine was in the course in 2005 or 2006, and described group discussion, paper-based tests, and a different former USF graduate (unrelated to this study) as TA. Modules were used as class assignments, as in all later iterations of the course. Sunshine later organized and improved the modules as a graduate student and wrote a new one. There was no textbook for the course, but a
series of handouts, most likely referring to the “Computational Geology” column series of 31 articles published in the *Journal of Geoscience Education* between 1998 and 2005 (Vacher 2005). For an example, see “Computational Geology 5-If Geology, Then Calculus” (Vacher 1999). Selected columns are still used in the course\(^{14}\).

Gilda was a student in the course in approximately 2008 and described there being no TA for the course. She recalled modules and paper exams. Classes began with quizzes that introduced new material, but said “you don’t really ever pass them” indicating a change from the homework review noted with Jam to a more background assessment and challenge of misconceptions that VR observed in much more recent iterations.

Luke took the course in approximately 2009 with Denis Voytenko (now Dr. Voytenko, on postdoctoral fellowship at New York University) as TA (Denis was TA for all remaining interviewees, and gave his permission to have his name used in this work; see Appendix C). Luke described module assignments and Excel-based exams.

The exams being in an Excel format was also mentioned by Arya, from 2010 (this reference was the item in the first interview that raised the point of course changes being so ubiquitous). She experienced a lecture-heavy format with LV on one day per week and an Excel lab session with Denis on the other. After graduating she became an unofficial TA, assisting Denis, and noted that

\(^{14}\) For the complete list of the Computational Geology columns with full text as published in the *Journal of Geoscience Education* between 1998 and 2005, see [http://www.nagt.org/nagt/jge/columns/compgeo.html](http://www.nagt.org/nagt/jge/columns/compgeo.html)
during that semester that the LV sessions were different in format, with group discussions on solving a common problem. This format was similar to what Jam experienced 10 years earlier. Arya also noted that there was a campus-wide concern over a potential outbreak of H1N1 swine flu, leading to flexible attendance policies that semester. Lectures were therefore videotaped and posted on the Internet, which was done only that semester.

John Smith took the course near this time (“about five years ago”). He described a tough “brain buster” question to start the class, which is consistent with Arya’s unofficial TA account. Exams were in Excel, but may have included portions on paper. Modules were heavily featured, and homework assignments were also in Excel.

Sam took the course at approximately the same time (2010-2011). Sam’s memories were not clear, as, “I have a terrible memory.” She did not mention anything like the H1N1 circumstance (which would seem to be memorable even to those with poor memories), so would be presumed to be around 2011. She described Excel-based exams and module-based assignments, and the same class breakup of lecture once per week and a computer/Excel lab once per week with Denis.

John Doe took the course about 2012. Lecture days with LV were generally occupied with a topic lecture the first half, and a discussion the second half. Students were given a problem to solve for homework. Exams were mixed method (Excel and paper). Classes began with small quizzes to review material.
Lee took the course most recently among the interviewees, in 2013. She was in the first class that was asked to write word problems from scratch, rather than simply solve them. This new task ran into something of a hitch as there were no definitive due dates for the 4-5 problems. There was just a requirement that problems could not be turned in within a certain time of each other to avoid all being given in at the end. (In 2014 and 2015 specific due dates were given to avoid this bottlenecking issue.) Her assignments were module-driven, and she did not mention the format of the exams. However, she correlated exams and Excel by saying, “I didn’t really think of the labs too much when I was prepping for the exams”, which strongly implies paper exams (which were strictly what was used the next year).

The course was observed by VR during 2014, when Denis was in his final year as TA, with paper exams and module-based assignments. During the years Denis was TA, students would complete Excel-based labs that were intended to help with the skills needed for the module(s) of the week, but which were not graded. The fall 2015 course was taught differently, with VR as TA, and modules reduced in scope, more hands-on quantitative labs about 2/3 of the lab time, and all lab activities counting for course credit. Word problems were used more prominently, on a set schedule, and also for credit. Students were given problem sets and worked examples for study and practice purposes in accordance with the principles of Cognitive Load Theory. However, none of the changes since 2013 are directly relevant to the interviews, other than to point out that the course has continued to evolve. The course was then taught by Dr. Charles Connor in spring 2016, with a somewhat different focus, based loosely on the fall 2015 setup, but with the same overall intent.
Memories of the Course

This subsection deals with responses to the question, “please think back to when you took the Computational Geology course taught by Dr. Vacher at USF. Tell me what you remember from that course.” Memories related here are not necessarily the immediate response to this question, but may come from follow-up questions on the same topic.

Common Themes.

Table 2 indicates common themes among two or more interviewees.

Table 2: Common Course Experiences

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Topic</th>
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<tbody>
<tr>
<td>Excel</td>
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<tr>
<td>Modules</td>
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<tr>
<td>Napkin/BoE</td>
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<td>Polya/Problem solving</td>
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<td>Unit Conversions</td>
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<td>Difficult</td>
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<td>Brute Force</td>
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<td>Accessibility/Gender Equality</td>
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</table>

Luke called CG “probably one of the most important, for sure” of his courses, and Sam explained that the course was partially responsible for the choice of geology as a major. Jam said that specific events – discussed later – changed her life. Sunshine described herself as a “success story” from the course (her terminology was supplied independent of the “successful” criterion).
Since the earliest iterations of the course, Excel spreadsheet calculations, and later, PowerPoint modules that guided them were used in class and in homework activities. All the interviewees mentioned the use of Excel in the course, with only Medusa – who took the course before the modules were introduced – not mentioning modules in some capacity. Jam took the course in the semester immediately before the introduction of modules but recounted her experience as a graduate student (and TA for the course) in helping to assemble and use the modules for the first time.

Almost everyone – especially the regulators - mentioned unit conversions at some point in their interviews. Another common topic was quick estimation, also referred to as “napkin math” or “back of the envelope calculations”. Sunshine stated that,

I remember doing math on a piece of napkin that was Dr. Vacher’s goal for the class. That if you could sit in an airplane next to somebody and explain a math problem… on… a regular cocktail napkin, and you could draw a little diagram, that you were successful in his class.

Jam responded to the term “back of the envelope math” by saying, “yeah, I remember him using that phrase a lot.” Arya, who took the course with a man who later became her fiancé, said that they use “back of the envelope stuff all the time… just estimating… getting a good, quick figure.”

Most of the interviewees described the course as being challenging in some fashion or another. Arya described the exams as “very difficult”. John Smith described the grading for the course as
“brutal,” “relentless,” and “vicious,” but stated that everything in the course was “only for my benefit.” Jam related that the course had a reputation for difficulty such that “everybody was afraid to take it,” while Lee and Sunshine both described LV as “intimidating.” Medusa, who also took a hydrogeology course taught by LV, used the statement, “this was a Len Vacher class and by default it was a challenging class.” However, she stated that “challenging doesn’t mean bad by any means,” and that you “knew when you walked out of there, you were going to know what the hell you were talking about.”

John Smith described the course as “extremely challenging. But informative, and in the end a very beneficial course for me.” When asked to elaborate on how he found the course challenging, he said the following:

[The course] was meant to… force you to think things through thoroughly. Think deeply. He always said think deeply about things. And at first I kind of just thought well, I always think deeply, how can you not think deeply? But until, you know, things really started cooking in there, I got to know what meant by that. You really do have to dig, deep, for that kind of stuff, to… come up with the correct approach. You know there was sort of a multi-step process to everything we did in there, you know? You needed to first analyze the question on a… you know, face value level, take in the whole thing, and then you kind of broke it down, and, and then from there, you could kind of start formulating… a way to attack it, a way to approach it, and that was, in many ways, the most important part of it, because if, you know, if you started out the wrong way, you’ll
just end up going down a hallway and you’ll never get out… you’ll never get to the right answer.

This harkens to the four-step approach from *How To Solve It* (Polya 1945), which has featured heavily in the course throughout its time on campus. Polya’s method of problem solving involved the basic steps of (1) understanding the problem, (2) formulating a plan, (3) carrying out the plan, and (4) looking back. John Smith’s quote here, although it doesn’t mention Polya by name, seems a solid reference to the first two steps of Polya’s plan.

Indeed, he was not the only person to refer to Polya, with others doing so by name. Jam said, “he was really big on Polya at that time,” and then recounted steps one, two, and, emphatically, four, which she uses with her students today. Lee mentioned Polya, and described the method as “it’s so beautifully simple, and if you actually do it, it is incredibly helpful. If you actually do it. (…) That was his entire course, was just learning how to think through things logically in a step-by-step manner.”

Medusa and John Doe both described a technique for problem solving using long form calculations, inelegant means, and sheer tenacity rather than a formula or derivation. John Doe described this using the term “brute force”, saying,

Well, for me, when I had to brute force a problem, um, it was a combination and permutation problem, and I couldn’t figure out how to write the, ah, the equations or the formulas out, so instead I turned lists of data into ones and zeroes in Excel, and based on
those ones and zeroes, I did different calculations, like, uh, summing them, and this and that, to come to a, you know, final answer…

Medusa phrased it somewhat differently, saying,

…when in doubt, to go back and muscle it, is what he used to call it. There are elegant ways to do things, but there’s a rough thing to do just about anything, and if your brain’s not getting the elegant way yet, step back and muscle it. And work your way through it, step by step.

Medusa, Jam, and Sunshine – the first three interviewees, chronologically, to take the course – all made mention of the course giving a sense of belonging, accessibility, and gender equality not present in other geoscience and/or STEM courses they took at the time. Sunshine told a tale of a history of personal math avoidance, and her choice with three other women to take steps to overcome this tendency toward avoidance (see Unique Perspectives). Jam stated that as a product of the time she grew up,

No one ever said to me you’re a girl, you don’t do math and science, but it was implied everywhere. My last science class was 8th grade biology. And my last math class was 9th grade business math where I learned to balance a checkbook. And so… girls didn’t do math and science. It’s in my head. Sometimes I still shake my head why I’m a geologist, because I’m a girl.
Medusa said “and it was no longer, you know, girls can’t think in math terms versus boys it was (...) let’s go get to it, and when you can really do this, then I’ll give you credence and we’ll move forward, and that was his only criteria for the most part.”

Unique Perspectives.

Lee – who took the course most recently among the interviewees – said that,

He was always really good, I know in his exams he was always really good, about bringing applicable situations to when you would actually use this… method, um, or this particular topic, and so that was nice. It wasn’t just, here’s something, figure it out this way. It was asking you to actually go through things that you have learned in the course and decide what would be the best approach to figuring out the problem. And it was a real world approach and that was, that was really nice. I do remember that.

Luke had a peculiarly specific memory regarding the course regarding the “Deciviews” module,15 which is still used in the course.

For some reason I particularly remember one module that had to do with, uh… Rayleigh light scattering… I believe that was a module that class, um. (...) Um… I don’t particularly remember the exact work that needed to be done there, the uh, the… the math

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15 The Deciviews module can be found on the SERC website at

http://serc.carleton.edu/sp/ssac/national_parks/examples/34447.html
involved, I, but I do remember the concept of it, and being, you know, pretty fascinated by it, and maybe finally being able to answer that question “why is the sky blue?” If, you know, someone asked that, being able to answer it truthfully and scientifically, which… which I thought was interesting, maybe other people wouldn’t.

When Arya took the course, there was a scare regarding the H1N1 influenza strain on campus resulting in an unusual situation:

When the H1N1 was going on, so many people didn’t go to class, because they videotaped it, and, uh, there were like a handful of people that went to class, and I was one of them, and that made a huge difference. Those people who didn’t go to class didn’t do well. (…) I knew people who weren’t there, and they would always come to ask for help, or try to get information from us that were there. Even though it was still recorded, I guess it just wasn’t the same because you weren’t there to, like, ask questions and stuff like that. (…) it was the same people consistently came to class. The other people were taking advantage of the situation. (…) I thought it was so absurd that people would just skip class because they thought they could get away with it.

John Smith compared requirements from the course that later became applicable to his career.

That class… I mean, up to that point I had no idea how to convert between a hectare and an acre, you know, and by the end of it I could do it in my sleep, you know? There was all kinds of just great information embedded in it. That he just expected us to just know, you know? I mean, it was our responsibility to learn that stuff and know it and have it
locked down. Because you know, at the end of the semester, when the exam comes around, he’s not telling you what the diameter of the Earth is, you know? He’s not telling you the conversion factor between one thing and other, you know? That’s your responsibility to know that. And… that’s something that really carries through to the professional world. There’s all kinds of stuff like that, that you just have to know, you know? You can’t always look in your book, you know, you can’t always Google something, you’ve got to know what you need to know to do… the work, you know, and that’s… and that’s something he taught me in that class, and… and something he really grilled into us, is you know, learn these basic building blocks of things, because you should know them, there’s no reason not to know them. So, in that sense, I took a lot from it with me, you know, things that uh, didn’t seem important to me at the beginning, and then you know, at the end it’s just… there’s all kinds of stuff like that, you know?

Sunshine described the following somewhat colorful arrangement from her time in the course.

I became really good friends with, um, some ladies, uh, in the course… which we call ourselves “The Front Row Bitches”… So if anybody has met Vacher… he can seem very unapproachable at first, and not relatable… so there’s four of us. Four Front Row Bitches. We… did not succumb to Dr. Vacher’s intimidating aura, so we sat in the very front row. All four of us in the front row. Everybody else sat back behind us pretty far back. We wanted to learn. We wanted to hear what he had to say, and the only way to… truly be successful in his course was to be involved and to be… connected to Dr. Vacher, to be able to stop him whenever you have a question or be able to… ask him to
elaborate… So we sat in the front row and we asked him questions all the time… he was not used to that. (…) And all four of us are still very good friends.

Sunshine further explained how the course helped her take charge of personal shortcomings with respect to math avoidance.

I can now say being, you know, an educator and a, um, a person who studies how people learn and specifically looking at math avoidance that I did avoid math and I still do. I’m trying to overcome that as I’m sure lots of people are. So… for me to take that course, which it was a requirement for a geology, um, BS, I knew that I had to take a (sic) assertiveness in my own education and sit up front and be there or I was not going to succeed. I just knew that personally because of how I am, so. And that’s how the other four girls, the other three girls were as well. You know, we just knew that’s what we wanted to do. We wanted to pass this course.

She later related a story regarding an experience that improved her personal confidence.

I was always kind of a math avoider, and I remember he… we had this one problem about… a meteor impact, and we were looking at the blast radius, so we were looking at trying to figure out how big the meteor that hit, based on the crater that it produced and then the ray around it. And… I remember because… because I’m still proud of myself because I actually answered a question and I answered it correctly. He asked the students “OK, now, what is, you know what are some of the measurements of the… the impact that we could use to figure out how big this meteor was?” And no one was saying
anything. And I’m like, well, this seems pretty simple to me, so I raised my hand. And he was like “Sunshine”… So I said “um, well, can’t you just measure the length of the ejecta? And figure out how fast it was coming that way?” And his face, like, lit up when I said that. I was almost cause now that that I’m a professor I know what he felt, like, she got it, she gets it! You know, like, and I used, you know that, um, that thinking that he was teaching us of writing math on the back of a napkin, of don’t think so much in the world of numbers, numbers, numbers. You’ve got to critically think about something. How can you look at a problem and figure out the answer that you need to from the data that you’re given? So, that was… I remember that being a defining moment for me. And I felt very happy about that, when I did that as well. (…) And the rest of the class looked at me like, how did you get that? I mean, saying it now seems so simple but it was… you were like, you just have a hole, how are you… how are you… I don’t know. (…) I got it, I got it, OK. Dr. Vacher’s happy today!

Jam told an extraordinary story relating to an experience in the course that shaped her future.

It was probably the first day of class. Uh, he taught about I don’t even remember about what. But I left… as I was leaving the room, I walked up to Dr. Vacher, and I said, “I just want you to know I don’t do math”. And he looked at me, and he didn’t respond as far as I can remember. And he just let that go. I was very proud of myself for saying that, because this is the course that nobody wanted to take. Everybody was afraid of him and… a little while into the semester when I was… I could hardly wait to get home every day to do the homework. It was the first time in my life I was ever successful at doing
any kind of a math problem, a word problem. The homework, Excel stuff. And about, I’ll
guess a month into the semester, he asked me if I remembered what I had said to him the
first day. And I turned red and said “yes, I absolutely remember that”. And he said, “You
know, [Jam], if you weren’t able to read, you would have been so embarrassed about that
that you would never have told me or anyone else. You should be just as embarrassed to
have said you weren’t quantitatively literate.” And that statement changed my life.

When asked, on follow-up, about how this changed her, life, she explained that it made her want
to be quantitatively literate. Jam further described that this led to a persistence, saying

I would struggle with the homework, but I would sit there and do it until I understood
what I was doing. I would do the math problems and be in awe of myself when I got an
answer in the back of the book that matched.

She then detailed a story involving an interaction with LV over a homework problem,

That same book, those same homework problems… if there was one specific time… I
struggled with them, but I worked. I really wanted to get… the answer. I wanted to know
how to do the problem. And… there was a time that I just wore myself out trying to
figure out this one problem. I could not figure out how to do it. And I was not good about
going to some professor’s office and asking for help. So it took a lot for me to go knock
on Dr. Vacher’s door. And when I said, you know, “I’m struggling with number 13, I just
don’t understand how to do it; I’m not getting the answer in the back of the book”… he
looked at me and said, “You’ll figure it out”. And I was pretty pissed actually when I
walked out of his office. And I went home and I sat there and played and played and played and played with that and I finally got it. I figured out what I was doing wrong and I was able to work the problem and in hindsight it was a good thing what he did. But to follow up on that, I would study in the break room a lot [SCA 512, a few doors down from LV’s office]. And he’d see me in there. And I, um, was in there one day, and I don’t remember if I was working on his homework or not, but he came in he said, “[Jam], um… you know the answer in the back to problem 113 is not right!” And I said “it’s not?” And he said “well, you didn’t get the answer in the back of the book, did you?” And I said “yeah”. “Really? How did you do that?” …and I just brazenly looked down and said “you’ll figure it out”. But I… I’m not really like that, I would never have… I don’t know where I got the guts to say something like that, but I pulled out my homework and I showed him how I worked through the problem to get that answer and I could see the light bulb come through in his face when he realized what he was doing wrong. Man, that was a special day for me. He never told me what he was doing wrong, why he wasn’t getting the answer in the back of the book. Was it the way the problem was worded, I think? I can remember what it was, it was drilling a tunnel into rock and calculating some, I don’t know, angle or some pressure or something in there. So yeah, that was a pretty proud moment in my life that I was able to help him figure out how to solve a math problem.
Jam later discussed how she learned more, conceptually, about what calculus and other forms of math really meant and why they were used, in just a few minutes in the course than she had in entire semesters of standard math courses.

Somebody says the word logarithm and I say, yeah, man, he made it so clear. (...) And I’ve said this to him, I’ve said it to current and former students in his class, and I’ve said it to people outside of USF. I really felt like I learned more in a ten minute discussion in his class about calculus than I learned in two semester sitting in calculus math class here at USF. (...) At the end of those two semesters [of engineering calculus 1 and 2], I didn’t know why you do calculus. I never got that a derivative was the slope of a line and that the integral was the area under the slope. Two semesters, I never got that. I... I learned how to take letters and numbers here, and then there was the equal sign, and I had learned how to change those same letters and numbers and make them different over here. And I could do it. I think I got an A or A- in calculus, which I was like, how did I do that? I didn’t understand it at the end. And in ten minutes, when he explained this is why... this is what a derivative, all it is is the slope of a line... oh, the light came on. (...) And... you don’t hear that in a math class. At least if you do, I wasn’t paying attention that day. The same... if they ever said a derivative is the slope of a line? I completely missed that.

Medusa – whose early iteration of the course involved a relatively large amount of calculus compared to later sections – described something similar regarding geology, math tools, calculus, and confidence.
The course… allowed me to see mathematics as a tool that I can realistically use in the applications of geoscience instead of viewing calculus etcetera as a separate thing from geology. Um, and it took the fear away. It was a very common theme at the time, um, that, you know, folks felt challenged by a lot of the math courses that they were in. They were having trouble with them. Some of them were even failing them. When these concepts really are quite central to geology. And Len saw them as central, didn’t understand why we weren’t, you know, functioning within both equally well, um, so he look at how those courses are being taught, and how geologists think, and created a course that took the fear out of math, which is huge.

When asked how this was accomplished, she responded as follows:

Well, he answered what I call the primary questions. Which actually may be a concept I got from Len, I don’t remember where I got it, it very well could have been Len. Primary questions being “so what?” and “who cares?” So, um, he went back to relating to the concepts that geologists work with every day. You know, a derivative is change over time, that’s all it is. Geology is change over time. Almost everything we look at in geology is change over time. Until he said that to me, in that sentence, I had never seen it, I had not seen a derivative that way, and I had not really applied, oh, that’s why I might want to use that in geology. Why this, the… the mathematics and the computations are so inherent in the application of geoscience. Um, and so he firstly made it relevant for us, and secondly, was able to get to the nuts and bolts of how you use it instead of just fluttering about with the theory that a lot of the courses were doing. You know, um, a…
this is more physics than calculus, etcetera, but you know, a ball’s coming at you at a certain angle, and if somebody hits the ball, how’s it going to go? Well, you know, in my mind, the answer to that was ‘home run’. You know, I didn’t… the nitty gritty of that didn’t matter to me, and Len was able, um, to help me understand exactly why I would want to know that. And why I would want to use these tools to get there. So it… he… he… made it a tool that I can use, and made it something I wasn’t afraid to use, and made it something I was excited to use and felt empowered by instead of somewhat fearful of.

Uses of the Course

This subsection deals with responses to the question, “Is there anything from the course that you used professionally or personally since graduating?” As with the prior question, responses may be from the original question or from related follow-up questions.

Common Themes.

Table 3 indicates common uses of course knowledge from two or more interviewees.
Table 3: Common Course Uses

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<thead>
<tr>
<th>Interviewee</th>
<th>Topic</th>
<th>Excel</th>
<th>Notes</th>
<th>Polya</th>
<th>Modules</th>
<th>Weighted Averages</th>
<th>Unit Conversions</th>
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Key: ☑ Item Present
    ☐ Item Not Present

Several students, speaking in a general way, stated that they use the material or learnings from the course on a daily basis. Lee, when asked this question (is there anything from the course that you used professionally or personally since graduating) said, “every day… every single day.” She later elaborated on this statement by saying, “I use Excel… I use computations every single day, and… it was really eye-opening to get to grad school and (…) to see it, the focus was way more on computation than I ever gathered when I was at USF.” John Smith responded to the question by saying, “definitely the Excel work. For sure. Every day of my life is a… I live and die in Excel at my job.”

This specific statement that Excel/spreadsheet work was commonly used was not unique at all (in fact, only Arya did not mention using Excel professionally, although she later said graduate
students needed to know how to use it well). John Smith went on to say, “I’ll write my reports with pen and paper if you want me to, but if you take Excel away from me, I’m… I’m dead.” Luke referred to reviewing the Excel sheets submitted for permits, and the knowledge for the course helping him to understand what he sees, “I learned a lot about Excel, which now Excel, you know, obviously I can look through a sheet and reverse engineer it, find out the calculations, things like that, that people have submitted to me.” John Doe mentioned Excel for both professional and personal purposes, saying, “I’m always pulling up Excel, and doing some statistics on, you know, financials or, uh, stocks, or anything that I’m, you know, interested in.” Sam said, “Yes, I definitely use Excel in my personal life for maintaining finances.”

Both Arya and Lee mentioned that they still have all their notes and labs from the course and refer back to them frequently. “I still have all my notes from both those classes and I actually still refer back to them,” said Arya, referring to both the computational geology course and a somewhat similar graduate QL-in-geology course titled Math Concepts for Professional Geologists. “I’ve used my notes… for other classes just to like, look at like vector algebra or something like that, that’s, you know, sometimes I don’t memorize those things… I have to go back and review”, she later said. Lee expressed it similarly, saying, “I actually still have all the labs and all our lab exercises just in case I forget to… I forget exactly how to do one thing.”

Sunshine and Arya mentioned using the modules in teaching, and Jam mentioned the use of Excel and the tutorial modules in her teaching as well. As a graduate student working with both LV and the course TA at the time, Sunshine said,
We actually created modules… pre-modules to the modules, to help students that go, ok, this is what a module is about, this is what Excel is about, these are the equations that you could be using in Excel. So kind of a, let’s get the students up, all on the same playing field, before we just throw this complicated module at them and possibly they don’t even understand the quantitativeness (sic).

The “pre-modules” she describes here are tutorial modules that are still used in the computational course and in several other courses to prepare for more detailed Excel work.

Two interviewees mentioned using averages frequently. Arya has a history of study and teaching in sedimentary geology, which includes the topic of grain size distribution in sediments. She discussed the need to use (and teach) weighted averages to determine the mean grain size of sediments. John Smith said, “Well, we’ll go to averages. (…) There’s different kinds of averages, and they do different things for different reasons, you know? There’s a right time to use an, um, arithmetic mean. There’s a, there’s a right time to use a geometric mean, you know?”

Several interviewees mentioned using QL specifically, or to the skills under its umbrella without using the actual QL terminology. Luke said that the course made him think about the mathematics he had already known, “but it made me think about it a little bit differently.” John Smith stated, “Quantitative literacy is one of those… it’s a life skill. Once you learn it you can’t unlearn it.” Jam, after stating that she makes her students do Excel exercises, said, “I want my students to be quantitatively literate.” Sunshine mentioned working unit conversions and other aspects of QL. “I ask questions at the end of the lecture.” She said, “Along the lines of quantitative literacy.”
Unit conversions were mentioned specifically by Luke, Sam, Sunshine, Gilda, and John Doe. Sunshine mentioned them in the context of the QL questions she asked in her classes, “I do your, you know, stereotypical assignment of unit conversions.” Sam’s primary response to the question was “one thing that I definitely do on a regular basis is convert you know, from, um, from elevation, height above sea level or something to feet below land surface.” Gilda added them as the second item she used frequently, saying, “And unit conversions, that probably helped a lot too.” John Doe mentioned unit conversions as proportions, “I’d say that proportions I use a lot, and on the other end of that is, um… uh, unit conversions.” The topic of unit conversions came up heavily in Luke’s interview (in answer to more than one question), with him saying in response to this question, “I hate to keep going back to unit conversions, but that’s definitely something that… was really stuck in my mind, to make sure you do them right.”

Arya, Lee, John Smith, and Medusa, discussed using statistics in their professional or personal lives. John Smith asked, “Are you introducing statistical error by, you know, setting up a certain way?” Lee said, “I use… the statistics that he went over… all the time.” Medusa had a very interesting way of expressing variation in human beings using standard deviation, saying, “I don’t seem to express myself or learn, um, in ways that fit, you know, that are within one standard deviation of the mean.” She went on to express how she used standard deviations to explain to her son his differences and exceptional abilities in terms of standard deviations and the population mean, and said,

And having been through a course like Len’s allowed me to see the concept so simply, instead of it be this weird calculation that I’d have to work really hard to be able to
function with. It’s a very basic concept to me, and it’s now a very basic concept that my
son uses every day to perceive himself. That’s a big deal.

Arya completed an MS thesis that used computers to perform detailed statistical analyses on
beach sands. In discussing how the computational course had given her a foundation for this
work, she said,

I felt like it gave me a little bit more of a starting point because I am not… well, I am
now, but I was not very strong in statistics, so with not having a strong statistical
background and doing a thesis that’s just highly related to statistics was very stressful but
I was able to go back and use my notes to help me along with just doing the basic
mathematics that were needed for that.

Unique Perspectives.

Sam directly linked the course to her ability to maintain personal finances using Excel.

Um, yes, I definitely use Excel in my personal life for maintaining finances or, um, things
of that nature. I have spreadsheets of how things are moving and where money is going
and all kinds of things, um, like that, and I probably would not know how to do a lot of
that stuff if it had not been for that class.

Gilda, like many of the interviewees, took both the computational geology course and the similar
graduate course titled Math Concepts for Professional Geologists. She related one use that was
relevant in her life that she learned in both courses (part of Polya’s first step).
I would say, um, I kind of was reminded of this from the graduate course, but what I have done since before taking the graduate course was if there’s ever any sort of question, I’ve gotten used to drawing a picture and labeling everything in order to better understand, you know, what to do to solve it.

John Doe said something regarding how the course changed the students’ thought processes about some terms that reflected a clear habit of mind consistent with QL.

I think, um, what the course did was make us wary of statements like “greater than” or “percent more.” Um, Dr. Vacher has a very, um, strict policy on using certain phrases to describe something, um, so description of percent more should mean, you know, percent more than and that was actually a small segment of his course, so I think what it made us, what it makes me do is when someone says something like that or a statistical phrase, um, I think about it and say, “is that what they really mean,” because I know mistakes are made all the time.

Arya served as an unofficial course TA after entering graduate school, and used her knowledge of course modules to help write introductory text documents for students that were intended to assist them in getting through unfamiliar terms or processes. “So I would just, I would use my previous, uh, experience to… help the students.” She also mentioned having used certain math skills from the course in her current occupation as a graduate assistant. “Matrix algebra is a big one and that… has helped me (…) I use a lot of vectors.”
John Smith discussed the minor variations in wording that potentially make a large divergence in meaning, summed up with the aphorism “words matter”.

In the professional realm, um, there are different geological facts that come in handy. You know, what’s the difference between a silty sand and a sandy silt, you know? Um, which of those holds water better than the other? You know, uh, what’s a dissolved component versus a total component, you know, things like that, differences, and that makes me think of another thing that he used to say all the time, that I still say to myself all the time: words matter. You know, and that’s the perfect example, what’s the difference between a silty sand and a sandy silt? To… to a non-geologist, that’s the same thing. Six in one half dozen. But really, they have a different meaning. You know, the placement of the words makes a completely different, you know, material. Words matter, and that, you know, that’s something that’s helped me write reports, it’s helped me, you know, get my ass out of trouble, you know, with regulators and stuff, you know? Like, you know, they come back trying to red light something I said, I’m like, ‘read what I said,’ you know? Think about what I said here, you know. Words matter. It’s not what you’re thinking it says, it’s what I said it says, because it’s only one possible interpretation, you know? Because that’s one thing I learned working with him, and you know, getting… you know, starting in the consulting industry, is, write things clearly, concisely, with limited interpretations, you know? You want to, you don’t want to get yourself in trouble by opening up to the peanut gallery where anybody can turn your… your paragraph into whatever they want to say.
In discussing quantitative literacy in depth, John Smith related QL to his personal life.

It [QL] sort of pervades… everything, you know? So it has impacted my personal life, for the better, of course, but things like that, you know? I’ll go into the store, I’m trying to, you know, get a deal on lemons, you know, I’m looking at it, and I’ll go, what’s the price per ounce here? You know, should I get the big lemons or the small lemons? You know, get the bag of lemons or should I buy them individually, you know? And it… the wheels start turning automatically now, you know, whereas I used to just, oh, $2, $1, I’ll get the $1 bag, you know? But it’s stuff like that happens all the time. All the time. You’ve got to think ahead, and you know, just analyze things. I’ve become a more analytical person because of it, you know?

Jam entered graduate school very shortly after graduating with her BS, “like a week after I graduated I started graduate school. Never intended to do that.” She described the process where the PowerPoint modules were first created when she entered graduate school working for LV.

So I got to see these just Excel spreadsheets there [in the undergraduate course]. He convinced me to work on a master’s degree. He didn’t want me to wait until fall, so now it’s the week of summer semester, it’s a week after spring break, er, a week after spring semester’s over, and I start working. And we’re sitting in this room [SCA 534, where the interview was conducted] and [LV] said he wanted to make these PowerPoint things that add content to build on what the spreadsheet wanted us to do. And so he had CorelDraw, which I had never used. And I had to use Archimedes’ principle of buoyancy and show lithostatic adjustment in the continents and I loved it, because at this point it’s art to me.
now. And I got to play and maneuver objects and things and get that visual aid that I was lacking when I took the class, and I knew that he was going to be using those in the fall semester.

Jam then served as the TA for the course in graduate school, and her experience in both doing the spreadsheet work in the course before modules were made, and in making the first modules, helped her assist the students. She said “now the students had these PowerPoints that they could use to help them work their way through it. And because I was instrumental in making some of those, I already understood them. That helped me as a TA.”

Lee is in graduate school studying oceanography, and “I manage a large data set”. She said, “I try to apply numbers to things that I’m doing every day.” When discussing specific skills she uses frequently from the computational course, she stated “I use percent differences and… the statistics that he went over, Excel formulas and… arrangements all the time.” She suggested that a significant purpose of the computational geology course was to help “not be overwhelmed by the numbers”.

Although the use of Excel itself was by no means unique, Sunshine explained using Excel for a very specialized purpose:

Well, ever since that course, I have used Excel. I never really used Excel before it, and I love Excel now. I use it for everything. I used it for my chemical data that I collected for my rocks for my master’s. I used it to create my budget for my house for, you know, my husband. I used an Excel spreadsheet to show my husband that we needed to trade in our
other car and buy a new car because it was going to be gas efficient and we were going to save money. (…) And when I did the Excel spreadsheet for convincing my husband to buy a car, I had… I made the spreadsheet up and I had the, um, the amount of what gas would cost as a variable, the amount of miles he was traveling, um, what different types of gas… miles per gallon for each car we were thinking about buying. Then comparing that to what we were spending right now with the car that he was driving, so looking at gas and tolls and then comparing that to how much it would cost… how much it would save us if we bought a new car that was gas efficient, but we had a car payment, but the car payment was still, the car payment plus the gas was still lower than having a car that was already paid off but horrible gas mileage. And I made a whole spreadsheet that he manipulated and played with all these different variables and it changed the bottom number to figure out how much we would save every month. And that convinced him and we went and bought a new car.

Sunshine also used Excel to explain to a student a unique situation that helped that student understand how to pass a course.

Last week I made an Excel spreadsheet for one of my students who… was going to fail. (…) And so what I did is I actually created an Excel spreadsheet of the labs she has turned in, the quizzes she has turned in, because the labs were worth 40% of the class, the quizzes were worth 30% of the class, and I color coded the cells for the ones that she could manipulate to see what she would need to get on the labs and the quizzes to get the grade she wanted at the bottom. So at the bottom I had her weighted grade calculated so it
would change whenever she changed those cells. And that’s all stuff that I learned from computational geology.

Sunshine additionally spent time in graduate school employed by LV organizing the modules over summers, and later wrote a module which is on the Science Education Research Center\(^{16}\) (SERC) website. She uses the modules in her current teaching assignment to help students learn QL in geology.

Medusa was asked whether she has used anything from the course professionally or personally from the course, and the following exchange ensued:

M: Almost all of it. Um, now I can’t say I that I actively…

VR: Can you elaborate on that?

M: Sorry, I don’t know that I actively, I mean, I don’t actively do these calculations any longer. I, you know, I don’t actively write out, you know, um, these equations, however, the work I do…

VR: Now why would that be?

M: Um…

\(^{16}\) The Science Education Resource Center, housed at Carleton College, [http://serc.carleton.edu/index.html](http://serc.carleton.edu/index.html)
VR: Is it because of the computer does it, or because you’re above the level in the company?

M: Several reasons. Both. Um, now I’m not the person who does the technical aspects as much anymore, I’m more of a project manager, and person who does design for projects… So when I need calculations run, um, I have folks that do that. Um, and of course we have models that we run, however, I… I… I make folks go back and show me that they can do the calculations if they’re going to be running the model. Um, one of the strongest things that we learned from… from this course was that you know, you can make a model do anything. And you have to able to, I guess, things have to be able to pass the smell test. It has to make sense. It has to be valid. You can make a model do anything based on the inputs but unless the… um, the math is solid, the calculations are solid, the model is meaningless. Again, so what and who cares? Why… why did I run this model? I would say I use the information that I learned in his class to vet the validity of models that I see every day. I did that as a regulator, um, and I do that now.

**Suggestions for Undergraduate Learning**

This subsection deals with responses to the question, “what would you like to see students in computational geology learning that would help them succeed professionally after graduation?” As with prior questions, responses may be from the primary question or related follow-up questions.
Common Themes.

Table 4 indicates common suggestions from two or more interviewees.

Table 4: Common Suggestions

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Status quo plus</th>
<th>Excel</th>
<th>Unit Conversions</th>
<th>Large Data Packages</th>
<th>Communication</th>
<th>Other programs</th>
<th>Graphs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medusa</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>Jam</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>Sunshine</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>Gilda</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>Luke</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>Arya</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>John Smith</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>Sam</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
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<tr>
<td>John Doe</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
<tr>
<td>Lee</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
<td>Item Present</td>
</tr>
</tbody>
</table>

Key: Item Present | Item Not Present

Several current topics and skills covered in the course were indicated as being considered relevant for continued use in the course by multiple interviewees. Most of the interviewees indicated that the current format of the course (as they understood it) was essentially positive, but did make some suggestions for additions or improvements. Not all of these are practical for addition to the computational geology course itself, as will be discussed later, but some may be practical for other courses, existing or otherwise.

Luke, Gilda, and John Smith argued for the status quo (although it should be noted that the status quo has evolved since the time each of them took the course), plus some additions. Luke stated,
“It pretty well touches on everything.” Gilda said, “I think the subjects of, you know, it feels like computational covered a lot of ground, a lot of material, different types of stuff.” Luke described the course as “pretty well representative of what you… need to know.”

Arya, Jam, Lee, Gilda, and John Smith specifically mentioned continued teaching of Excel for geological-mathematical problem solving. Jam and John Doe mentioned unit conversions being relevant for program graduates to know (although several other interviewees who did not mention this need had separately mentioned using them in their own professional lives). John Doe and Lee strongly recommended using large, real-time data sets and learning how to work with different types of graphs. Arya and Jam mentioned teaching the order of operations, as it was very relevant to entering data in spreadsheets.

Sam, Sunshine, and John Smith mentioned technical writing and/or the ability to communicate about math. Sunshine and John Smith specifically mentioned the term “quantitative literacy” in their interviews, unprompted, and John Smith recommended that instructors could “include a more meticulous… module on writing or whatever part of the course it is, that would be really beneficial.” Sunshine elaborated at greater length, saying, “So I think to have students to be able to communicate what the numbers mean, what the data actually means and to be able to communicate what standard deviations mean, what variations mean, what… what their data is showing you…”.

Specifically regarding such topics as standard deviation and other simple statistical analytical terms, Lee, Sunshine, and Medusa mentioned either statistics or standard deviations, while Arya and John Smith strongly indicated the need to teach weighted averages.
Lee and Gilda suggested that students not only continue to learn Excel, but that they learn additional computer programs or languages such as Python for dealing with problems solving or data packages.

**Unique Perspectives.**

Arya, who teaches labs, was asked in follow-up what she found her students lack, quantitatively. She replied, “Weighted average, oh my gosh, you have no idea.” She explained that students would be explicitly warned that they would have to perform a weighted average for their unit test, and “there are still people that just… mess it up on the exam.”

Lee responded to the question by saying,

> Learning how to manipulate large data packages. Larger than what Dr. Vacher would give in his module, like, um, real time series, um, instrument data is huge right now, um, so actually going online and downloading um, large real time packages of… like a month’s worth of data from an instrument that’s been collecting every hour and learning how not to be afraid of a document that is… very large. And, uh, just learning how you would attack that. What would be relevant to pull from that?

Medusa had a very different pair of requests regarding what students should learn in the course. First, she recommended,

> I would love to see him… go through and… give the primary calculations used in the… majority of areas of geology. Meaning, you know, hydro, right? (...) Ok, so the basic
calculations that are used for geophysics, the basic calculations that are used for hydro, the basic calculations that are used for a... chemical transport model. (...) You know, these are... the things where the majority of the work is in our business. Um, and so I would love to see a few things that are, you know, applied in that way.

Her other suggestion was a return to something she noted as being done during the first couple of weeks of the course when she took it in 1997, where the instructor would “have some wiggle in there to cover those first couple of days when people say this is what’s bothering me. This is why I’m here, to figure this thing, that’s you know, I failed a test because of this thing.”

Sunshine had the most obvious “geologist” answer to the question, saying,

They needed to get out of the classroom. That’s one thing I didn’t like about that. If it was... if it’s going to... if you’re going to say it’s computational geology, geology is outside, why are we doing math inside? Why don’t we go outside and do some math? There’s math all around us. (...) So something like that would be really cool to do, um, in computational geology, to get the students outside and to know how it could be applied in computational geology because Excel and the modules are great in the world of, you know, computers and the type of geologist that wants to do that, which is where geology is merging toward, but there are still the geologists that like to go outside and to see how you can use that math if you were to be a volcanologist or if you were to be a hydrologist. How could you use that math on the fly, which is what Dr. Vacher claimed that his math was, was on the fly math that you could do on the cocktail napkin. Well, how do you do that beside just sitting in a classroom talking to each other?
She had said something similar to this statement earlier in the interview without being prompted. She was answering the question regarding experiences in the course, realizing she might be moving into the realm of another question, saying “I don’t know if I’m segueing into another question”. She made a statement where she didn’t expect to like the course but later found that she did, and thought the course was important. She followed this (with the above segue) by saying,

I do think that it… should probably be framed a bit more of… um… not focusing so much on the modules because that’s just one way to do something. There are multiple ways in which to answer a quantitative problem, and so I think it should be more of instead of computational geology it should be computational literacy within the realm of geology.

Sunshine also indicated that a knowledge of statistics was important. To emphasize her point, she mentioned that her group of friends (with the rather colorful nickname) would refer to themselves in an unusual way when someone said something odd. They would say to the offending member, “you are so not one sigma”. This comment is a reference to the Greek letter sigma (σ) which is generally used to indicate the population standard deviation. The statement indicates that the person being chastised is outside of one standard deviation from the population mean, and is therefore not near an average or mean response. (However, only someone literate in basic statistics would get the joke.)

Additionally, Sunshine recommended that students be put in a situation where an obvious answer could not be obtained, as this would simulate a real life scenario. “One thing I would like to add
is if you can’t figure out the answer or you can’t figure out what to do, then what do you do? Where do you go to figure out the answer? Um, that was one thing I don’t really remember learning too much. It was more of a, here’s a problem, this is how you fix it. Ok, so… is there a resource out there that the students can go to to figure out a certain problem that they’re not sure about? Um, is there a way… you know, presenting a student, maybe presenting the students with a problem that is not so straightforward, um, not necessarily implying that Dr. Vacher’s were straightforward, but more or less did it have a straightforward answer, if that makes sense.”
Discussion

Although this thesis is by its very essence a qualitative study, as an instructor in QL the author cannot resist the temptation to apply some degree of quantitative analysis to the interviews. The average – the unweighted arithmetic mean – of all interviews (by length of recording) was 36.7 minutes. The mean for the regulators was 23.7 minutes, for consultants 33.9 minutes, and for academics 48.6 minutes. Further examination of these data shows that the ranges of time for these groups are rather interesting in where they do and do not overlap. The overall range was from Gilda (19:53) to Jam (56:51). Regulators ranged from Gilda (19:53) to Luke (31:06). Consultants ranged from John Doe (25:17) to Medusa (39:40). Academics ranged from Lee (43:40) to Jam (56:51). This spread indicates that the range of academics (which includes four people rather than three in each of the other two groups) doesn’t overlap either of the other groups, and there is only a small overlap between the regulators and consultants.

The constant comparative method was used to analyze the transcripts, which as discussed previously, involves physically coding the responses where applicable, but also making analysis as the data are processed, and comparing the various interview transcripts to each other. The constant comparative method became central to what is known as grounded theory analysis (Strauss and Corbin 1994). The method seems to indicate that analysis is done in real time, as opposed to prior methods where judgment is suspended until all coding was complete. In reality, some combination of the two is the norm. One cannot sit in an interview room with a participant
and hear them speak, listen to the interview recording, transcribe the interview word-for-word, correct the transcript for errors, and then code the transcript without having (at least informally) come to some degree of judgment about the meaning of the codes. Contrariwise, the viewing of fully coded transcripts as a whole gives some insights not apparent on the face of things during the initial stages of the interview and transcription processes.

In this case, one method used for coding was to highlight significant passages in the transcripts. Of note in this method was that different colors were used in highlighting – yellow was arbitrarily selected for commonly used statements or codes, like “unit conversions” or “Excel,” while purple was used for unique perspectives that related relevant information, like Jam’s story about quantitative illiteracy. When comparing the transcripts in the most “macro-visual” fashion possible – that is, to look at them at arm’s length after the coding, without attention to detail – it became apparent that the coding from the regulators was almost exclusively in yellow. That is, they had relatively little to say that was not also said by either each other or one or more persons in the other groups.

By contrast, certain academic and consultant transcripts are littered with large blocks of purple – Arya, Lee, Sunshine, John Smith, Jam, and Medusa, specifically – which tells interesting things about what each group has told us. When sitting in the interview room, the regulators had difficulty remembering details of the course, or much of how they used course materials beyond Excel and unit conversions, and this limited memory may relate to how they use QL in their work. Regulators work within somewhat strict government constraints, and they may be responsible for large numbers of case files. A larger emphasis may be placed on determining
whether an item or permit meets set criteria than in taking time to think deeply about the meaning of the problem. This statement is not intended as a slight on our regulators, but a recognition that their jobs may call for a different use of quantitative literacy than what we saw from the consultants. Work as a regulator calls for efficient fluency in quantitative skills (including Excel) but not necessarily as much original thought or problem solving.

These job skills contrast with the work of a consultant. Having spent time as a consultant, the author can appreciate that QL is needed for solving the types of problems inherent in this field, and one must think conceptually. However, there is a push to solve things quickly and efficiently as the scientist’s time is billed to the client by the hour, and project budgets are not forgiving. By comparison, clients, regulators, and supervisors tend to be unforgiving of mistakes that do not find environmental contaminants, misinterpret flow direction, or make similar mistakes; a premium is thus placed on efficient but deep quantitative thought. The two consultants who told the longest stories, and whose stories contained the most unique coded responses after analysis, were Medusa and John Smith. These individuals have both already completed MS degrees, and thus have some overlap with some of what might be expected from our academics.

The academics interviewed tended to speak the longest and have some of the most original things to say, with Sunshine and Jam being especially unique (it is perhaps not a coincidence that these two had the most teaching experience). This loquacity perhaps speaks to the demands of the academic life, where the quality of thought and results are of the highest importance and hours spent working on a project are not considered. Additionally, the demands of incorporating
quantitative problems into student assignments and in encouraging, grading, and instructing students in QL also require original thought and a breadth of QL skills.

Demographically, the interview group consisted of seven women and three men. Although a group consisting of both genders was desired, no specific action was taken to set a certain balance (or lack of balance). As previously indicated, the three interviewees who took the course first chronologically – all of whom were women – made references to the course imparting a sense of gender balance and belonging, and in some cases implied that this was present more so in this class than in other STEM courses they had taken to that point. This issue was not something the interviewer specifically asked about – interviewees brought it up on their own – and the fact that it did not come up in later interviews may mean nothing, or it may indicate that the general state of gender treatment in STEM courses had begun to change.

When this demographic note is taken into account, it should also be noted that the faculty of this university department noted the need for the skills and concepts taught in this course (independent of other core geology courses) some 15 years before the Summit on the Future on Undergraduate Geoscience Education reached the same conclusion. When this observation is combined with the gender equality issue (suggested here but not studied rigorously) it begins to set the impression that the phrase ahead of the curve might be very appropriately designated to this course in anticipating the needs of both the students and the field. Further study is appropriate and relevant given national interest in issues of gender equity in geoscience education.
Outcomes

As discussed in the Introduction, the product of interest with respect to this course is student learning outcomes. The primary desired student learning outcome, as has been previously stated, is for the program to produce quantitatively literate geologists. However, per the Introduction section, the QL term is a broad one, and students meeting this objective would also meet a number of more focused student learning objectives.

When discussing the course with LV, he stated that he viewed knowledge learned as coming in three varieties: skills, facts, and concepts (LV did not have a source for these terms and appears to have made them up from his own extensive experience in education). In “Conceptions of Scientific Literacy: Identifying and Evaluating Their Programmatic Elements”, (Norris, Phillips, and Burns 2014) a somewhat similar breakdown was made, with objectives being broken down into knowledge, capacities, and traits. Where LV’s terms above involve a breakdown of knowledge, this descriptive system includes learning beyond what LV described. However, the terms overlap somewhat. Norris et al. use the term capacities, which describes the ability to perform an action; this term as described is essentially the same as LV’s skills. If an attempt is made to combine these ideas – LV’s breakdown of knowledge, Norris’s objectives, and the notion of student learning outcomes – what is the result?

In Table 5, examples are given for several different varieties of student learning outcomes, broken down by category, with examples from the transcripts. Knowledge is broken down into facts and concepts. Capacities and skills are listed as being the same item. Traits are listed as a separate student learning outcome.
### Table 5: Student Learning Outcome Examples

<table>
<thead>
<tr>
<th>Student Learning Outcome/Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge/Facts</strong></td>
<td></td>
</tr>
<tr>
<td>Orders of Operation</td>
<td><em>You have to know the order to do the calculations in or else you’re going to be wrong</em> – Arya</td>
</tr>
<tr>
<td><strong>Knowledge/Facts</strong></td>
<td></td>
</tr>
<tr>
<td>Conversion Factors</td>
<td><em>He’s not telling you the conversion factor between one thing and another… that’s your responsibility to know. And that’s something that really carries through into the professional world.</em> – John Smith</td>
</tr>
<tr>
<td><strong>Knowledge/Facts</strong></td>
<td></td>
</tr>
<tr>
<td>Excel Functions</td>
<td><em>I think I have probably used every single Excel function that Dr. Vacher showed us.</em> – Gilda</td>
</tr>
<tr>
<td><strong>Knowledge/Concepts</strong></td>
<td></td>
</tr>
<tr>
<td>Geology and calculus are inseparable</td>
<td><em>A derivative is change over time, that’s all it is. Geology is change over time. Almost everything we look at in geology is change over time.</em> – Medusa</td>
</tr>
<tr>
<td><strong>Knowledge/Concepts</strong></td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td><em>What the course did was make us wary of statements like greater than or percent more.</em> – John Doe</td>
</tr>
<tr>
<td><strong>Knowledge/Concepts</strong></td>
<td></td>
</tr>
<tr>
<td>Logical Processes</td>
<td><em>That was his entire course, was just learning how to think through things logically in a step by step manner.</em> – Lee</td>
</tr>
<tr>
<td>Student Learning Outcome/Type</td>
<td>Example</td>
</tr>
<tr>
<td>------------------------------</td>
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</tr>
<tr>
<td>Capacities/Skills Excel</td>
<td><em>I learned a lot about Excel... I can look through a sheet and reverse engineer it, find out the calculations... that people have submitted to me.</em> – Luke</td>
</tr>
<tr>
<td>Capacities/Skills Unit Conversions</td>
<td><em>Converting, you know, from different units and that sort of thing.</em> – Sam</td>
</tr>
<tr>
<td>Capacities/Skills Communication</td>
<td><em>If you could sit in an airplane next to somebody and explain a math problem on a... cocktail napkin, and you could draw a little diagram, you were successful in his class.</em> – Sunshine</td>
</tr>
<tr>
<td>Traits Quantitative Literacy</td>
<td><em>I want my students to be quantitatively literate.</em> – Jam</td>
</tr>
<tr>
<td>Traits Confidence</td>
<td><em>He made it a tool I can use, and made it something I wasn’t afraid to use, and made it something I was excited to use and felt empowered by instead of somewhat fearful of.</em> – Medusa</td>
</tr>
<tr>
<td>Traits Analytical Thought</td>
<td><em>I’ve become a more analytical person because of it.</em> – John Smith</td>
</tr>
</tbody>
</table>

Alumni did not specifically discuss facts at great length, but the quotes in Table 5 were relevant to the facts that these particular alumni remembered some various number of years after
graduation. When they did speak of facts, alumni generally talked about the facts rather than mentioning the facts themselves (e.g., John Smith mentioned conversion factors but did not actually supply any). Regulators, generally, discussed skills/capacities they learned (e.g., Excel usage, unit conversions). Other groups also noted these skills, but also noted concept knowledge. The academic and consultant groups also noted traits about themselves relevant to the course, down to Sunshine saying, “I’m kind of a success story for Dr. Vacher.” It should be noted that these statements are generalized, as each individual made some statements that could qualify under almost any category.

When the interview transcripts are compared to the general list of relevant skills identified by the Summit on the Future of Undergraduate Geoscience Education Survey, the following major skills sets were noted:

- Problem solving/critical thinking
- Effective communication
- Strong quantitative skills and ability to apply them
- Strong computational skills, ability to use large datasets

The quotes from Table 5 seem to indicate that these four skill sets are met by these interviewees, with some degree of uncertainty inherent. That is, the interviewees were discussing their own use of the skills, rather than being asked to demonstrate them; we are taking them at their word that
they in fact do know how to communicate and solve problems (their continued employment would seem to bear these skills out).

**Reflexivity**

This thesis contains bias, like any other qualitative study. The biases will be outlined so that the weaknesses of this thesis can be identified, and so that future studies can minimize concerns raised by these biases.

The primary concerns relate to the study population. This study was not intended to be representative of the general population of students who took this course over the time it was offered. This lack of random selection constitutes a selection bias.

Part of the reasoning behind allowing this particular selection bias was that this study was not intended to be the terminal point for this line of inquiry, as discussed earlier. The author of this study intends to continue this thesis study into a logical series of long-term projects, which will include a survey given to a wider, more representative population of course and program alumni. One purpose in sitting down in a mostly open-ended interview setting with successful alumni was to allow interviewees to provide information to frame future questions that could be asked to a more representative alumni population. The selection was also based on the idea that if one wishes to know whether a course helps a geologist become successful, one begins study with the successful alumni, and then moves onward to the general population. This potential narrowing of responses due to selection bias is also why a range of geological occupations was selected, as one size may not fit all occupations. Unfortunately it was random chance and poor scheduling
luck that resulted in certain limitations within the public/private/academic sector pool of candidates.

Additionally, what constituted a successful alumnus was entirely subjective, and entirely decided by LV. It is not suggested that ‘success’ is anything that was quantified for this project. Academics were not asked for ratings, or grant or research output, or graduate GPA. Consultants were not asked for salary reports, or projects generated for their company, or billable hours logged. Other course instructors with similar alumni groups may have asked different subjects to interview, and may have produced different results. As above, these interviews should not be taken as being representative of the general population that took the course.

This selection bias also included convenience sampling. This project was undertaken with a minimum of funding (no grant funds were used, but LV provided non-grant funding for recording equipment and computer software). The majority of the persons interviewed were therefore selected as being near the Tampa campus of USF, with the exception of “Lee.” While the consultants interviewed were all locally based, their busy travel and field schedules made scheduling interviews difficult, and this situation made a video conference interview for “John Doe” necessary.

A secondary concern is one of confirmation bias from the interviewer. The interview protocol was rewritten before submission to IRB to avoid leading questions with the assistance of the thesis committee, but some degree of leading in follow-up questions was noted in certain cases, especially for those interviewees who had significant trouble remembering events of their past in
detail. The author has avoided relying on any such information as much as possible by not quoting those passages, although the full transcripts are unaltered.

Lastly, through the time the interviewees took the course, both the computational course and Len Vacher the instructor were, to a certain extent, intertwined, as all interviewees were his students. To have students discuss their experience in the course invariably and inevitably involved significant portions of the interviews being about LV the person and instructor. This course can and must go on beyond the career of any one person, so wherever possible those portions of the interviews which focused more on LV than on the course have been avoided for analysis, unless there was some overriding reason to include them. This thesis is not a study of one person’s teaching style or philosophy. Those portions of the interviews which either appeared to have been overly leading on the part of the interviewer or focused primarily on the instructor rather than the course are still part of the transcript record, but less focus has been given to them for the analysis and direct quotation.

Related to this discussion is the concept that a significant portion of those persons interviewed felt they owed some debt of gratitude for their position in their career to LV for his teaching, assistance, and guidance in and out of the classroom. (Some expressed this feeling on record, while others have discussed it informally). Several of these interviewees were partially or completely advised by him during their time as graduate students at USF (including at least two for whom he currently sits on graduate committees), or assisted in relations with potential employers or the USF Geology Alumni Society (a significant source of employment networking resources for USF geology graduates). As mentioned above, this study is not about any one
person, but it must be acknowledged that there is an inherent reciprocity in the selection bias mentioned above in that these interviewees are highly unlikely – even given anonymity – to say anything particularly critical of LV or the CG course. This lack of criticism should not be taken as evidence that such negative outcomes don’t exist.

The author must also acknowledge that his own interests are tied up in those of this course, given his belief in its value and a desire to teach it in the future, and this involvement presents an opportunity for bias to be introduced (especially, but not limited to, confirmation bias).
Conclusions

Alumni Narratives

One of the purposes of the study reported here was to collect and tell the stories of successful course and program alumni – when possible in their own words – to a depth that would not be possible in surveys. The alumni responded with stories of a depth and breadth that surprised the author in a profoundly positive way.

The course that has evolved over 20 years is, and has been, many things to many people. The course moved from a spreadsheet-focused problem-solving course to one that combines spreadsheets with self-guiding PowerPoint modules. It has now moved beyond this original focus to include more physical hands-on activities and problem writing.

It is clear that the course was memorable to most of the consultants and academics, and at times transformative. Words like “empowered” and “success” were used to describe how the course made some of these interviewees feel. All of the interviewed persons viewed the course positively and found it useful both professionally and personally. In conjunction with the rest of the undergraduate curriculum, the computational geology course appears to have helped to make the interviewees into quantitatively literate geologists. It can also be presumed that skills and habits of mind learned in graduate school and on their various jobs have also contributed to their state of quantitative literacy.
The alumni suggestions for course changes include several items that have already been adopted (although the interviewees were not aware of the current changes when they made their own suggestions). Sunshine suggested additional outdoor time, which has been piloted by Chuck Connor and the author in spring 2016. John Doe and Lee recommended additional computer programs, which has been briefly touched on in the spring semester version as well. However, a discussed potential follow-up course to Computational Geology would be Algorithmic Thinking, which would continue the problem-solving goals of the CG course in a more advanced computer programming environment. Additional changes are being considered for the fall 2016 semester, possibly including additional student writing activities.

**Student Learning Outcomes**

The primary desired student learning outcome for this course – quantitatively literate geologists – seems to have been clearly achieved for the study population. Sunshine, Arya, and Jam incorporate QL into their teaching. Medusa, John Smith, John Doe, and Lee use QL to manage large projects with significant quantities of data. Luke, Sam, and Gilda perform water regulation and permitting duties that require quick and easy use of numbers, data, spreadsheets, and number-laden communications assembled by other parties. All of the interviewees are to some level or another quantitatively literate geologists, and all described specific instances or activities where they started to become quantitatively literate in computational geology.

The course appears, on the face of this study, to be a resounding success, but considering the limitations of the study, do these apparent results actually apply to everyone who took the
course? That is not possible to say at this time, and further study is recommended to answer this question.

To put this in a different way, each of these geologists appears to be quantitatively literate, and clearly so. However, since only this selected list of successful geologists was interviewed, is this also true for the larger population of geologists (or those who have gone into other fields) who have taken the course in the past? Additional studies are recommended.

**Next Steps**

This work, although done partially as a master’s thesis, is primarily a study on the past of the USF Computational Geology undergraduate course and its potential implications to the present, both within the community of USF geology and within the wider realm of the geoscience education field as a whole. However, of greater importance is the future of the course as a prototype for the needs of that wider audience.

**Proposed Future Studies**

The study in this thesis appears to strongly link the computational geology course to quantitatively literate geologists in a variety of professions. However, since the study does contain bias, the population was small and non-random, and no evaluation of the course itself was performed, a need for additional studies is indicated. The need to link this course and its outcomes more strongly with the needs of the geoscience education field at large must also be considered more carefully. The following study projects are tentatively proposed:
• Development and implementation of an online survey, given to a population representative of all course alumni (as much as is possible), to determine the level to which they feel the course and program prepared them with the necessary quantitative skills and habits of mind for professional success. See below for proposed questions. The survey would be to determine, in part, whether the analysis and conclusions drawn from these interviews are reasonable to apply to the general population of course alumni.

• A second survey given to a randomized national population of geologists (via, for example, the mail server of a professional organization, with permission) to determine the level to which the larger group felt prepared with the quantitative skills and habits of mind, as above, by the program they completed. The two survey results would then be compared.

• Development and implementation of an assessment instrument for the course to determine the effectiveness of QL instruction in a geology setting, and which would allow the users to test the effects of minor or major changes within this course (or another similar course).

Survey Questions.

As mentioned in the reflexivity section, one purpose in this current study – and one solution to the selection bias inherent in it – was to identify potential questions for a survey to be asked to a larger and more representative population. The following questions, which it must be stressed are at this point tentative, are proposed for a future survey. (The final questions would be submitted
for approval to the USFIRB prior to conducting such a study). The survey would be conducted online and would include a mix of short answer and selection/checks.

Demographics:

- Approximately what year did you take computational geology? (text)
- Approximately what grade did you earn in the course? (check boxes for A, A-, B+…)
- What geoscience-related careers have you held since graduating from USF? (check all that apply)
  - Regulatory (SWFWMD, FDEP, USGS, FGS, etc., box entry for entity)
  - Consulting/private sector (environmental, mining, oil/gas, box entry for type)
  - Academia/teaching (secondary, community college, university)
  - Graduate school (separate check box for USF)

[NOTE: It remains a possibility that questions a respondent is directed to may be stratified based on the results of one or more responses, such as career path. The feasibility of this concept has yet to be determined and may be used or abandoned. It is likely that a preliminary round of sampling will be performed prior to the major event.]

- On a scale of 1-5 where 5 is the highest, to what level do you or have you used Excel or similar spreadsheet programs since graduating?
- To what level have you used other quantitative software (other than other Office type products) since graduating?
• How often do you use quantitative skills in your personal life? (1-5 never to daily)
• How often do you use spreadsheets or other computer programs to assist you with computations in your professional life (same)?
• How often do you use quantitative skills in your professional life? (same)
• How often do you use spreadsheets or other computer programs to assist you with computations in your personal life (same)?
• To what degree do you feel that the undergraduate computational geology course provided the quantitative skills and habits of mind you use in your career as a geoscientist? (1-5)
• To what degree do you feel that the undergraduate geology course curriculum not including computational geology provided the quantitative skills and habits of mind you use in your career as a geoscientist? (1-5)
• To what degree do you feel that the entire undergraduate geology course curriculum provided the quantitative skills and habits of mind you use in your career as a geoscientist? (1-5)
• Text entry: What quantitative skills, knowledge, and/or reasoning ability from the course do you use in your professional or personal life?
• Text entry: Name ONE thing that could be added to the computational geology course that would improve students’ chance of professional success.
• Text entry: Name ONE thing that could be subtracted from the computational geology course without losing the essence of what the course is about.
Text entry: Name ONE thing outside of computational geology that could be added to the geoscience/geology program that would improve students’ chance of professional success.
References


Appendix A – USF IRB Certification
June 17, 2015

Victor Ricchezza

School of Geosciences

4202 East Fowler Drive

NES 107

Tampa, FL  33620

RE: Expedited Approval for Initial Review
IRB#: Pro00022615
Title: Alumni Narratives on Computational Geology


Dear Mr. Ricchezza:

On 6/17/2015, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents outlined below.
Approved Item(s):
Protocol Document(s):
Protocol Guideline Pro00022615 CG Alumni Narratives.docx

Consent/Assent Document(s)*:
Consent Form Pro00022615 CG Alumni Narratives.docx.pdf

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent document(s) are only valid during the approval period indicated at the top of the form(s).

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.
As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

Kristen Salomon, Ph.D., Vice Chairperson

USF Institutional Review Board
Appendix B – Demographic Information Sheets
Demographic Information Sheet

Please complete the following information sheet at the conclusion of your interview. Do not use your real name — use the pseudonym that was selected at the start of your interview.

Name:  

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

2010

If you remember, approximately what grade did you earn in computational geology at USF?

A

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

Yes, Finished Master's, working on PhD.

Did you take any other computational geology (or similar) course after graduating from USF?


What geology-related career or careers have you held since graduating from USF?

Graduate School
Demographic Information Sheet

e22615 – Alumni Narratives on Computational Geology

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: [Gilda] (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

Spring 2015

If you remember, approximately what grade did you earn in computational geology at USF?

B-ish

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

[Redacted]

Did you take any other computational geology (or similar) course after graduating from USF?

[Redacted]

What geology-related career or careers have you held since graduating from USF?

Hydrogeologist

[Redacted]
Demographic Information Sheet

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: John Doe (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

\[2013\]

If you remember, approximately what grade did you earn in computational geology at USF?

\[A\]

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

\[Yes\]

Geology/Geo

Did you take any other computational geology (or similar) course after graduating from USF?

Area

What geology-related career or careers have you held since graduating from USF?

Hydrogeologist, Radiochemistry Analyst
Demographic Information Sheet

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: John Smith (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

Approx. 5 yrs ago

If you remember, approximately what grade did you earn in computational geology at USF?

M.S. in geology

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?


Did you take any other computational geology (or similar) course after graduating from USF?

Project Manager/Staff Scientist in environmental remediation

What geology-related career or careers have you held since graduating from USF?
Demographic Information Sheet

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: Jam (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

Fall 2001

If you remember, approximately what grade did you earn in computational geology at USF?

A-

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

Yes MS Geology

Did you take any other computational geology (or similar) course after graduating from USF?

No

What geology-related career or careers have you held since graduating from USF?

Instructor
Demographic Information Sheet

e22615 – Alumni Narratives on Computational Geology

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: ___________________________ (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

2013 Fall

If you remember, approximately what grade did you earn in computational geology at USF?

A-

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

Yes

PhD (in progress)

Did you take any other computational geology (or similar) course after graduating from USF?

No

What geology-related career or careers have you held since graduating from USF?

Cerfal School

Filled by VR from Skype answers 9/6
Demographic Information Sheet

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: Luke (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

2008 or 2009

If you remember, approximately what grade did you earn in computational geology at USF?

B

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

Geology, M.S.

Did you take any other computational geology (or similar) course after graduating from USF?

No

What geology-related career or careers have you held since graduating from USF?

Hydrologist
Demographic Information Sheet

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: Medusa (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

Spring 1997

If you remember, approximately what grade did you earn in computational geology at USF?

A (And was Damn Proud of it!)

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

Yes. Earned an M.S. in Aqueous Geochemistry from

Did you take any other computational geology (or similar) course after graduating from USF?

Yes. Sedimentary Geochemistry

What geology-related career or careers have you held since graduating from USF?

Oil Exploration, Environmental Regulation, Environmental Consulting, Adjunct Teaching
Demographic Information Sheet

e22615 – Alumni Narratives on Computational Geology

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: Sam (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

2010-2011

If you remember, approximately what grade did you earn in computational geology at USF?

B

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

Yes, Masters, Hydrogeology program

Did you take any other computational geology (or similar) course after graduating from USF?

What geology-related career or careers have you held since graduating from USF?

Grad Student, Hydrologist
Demographic Information Sheet

e22615 – Alumni Narratives on Computational Geology

Please complete the following information sheet at the conclusion of your interview. Do not use your real name – use the pseudonym that was selected at the start of your interview.

Name: ___________________________ (Pseudonym)

In what year, or approximately how long ago (from Fall 2015), did you take computational geology (or a similar-titled undergraduate course) at USF?

________________________

If you remember, approximately what grade did you earn in computational geology at USF?

________________________

Did you attend graduate school after graduating from USF, and if so, where, to what degree and in what major or program?

________________________

Did you take any other computational geology (or similar) course after graduating from USF?

________________________

What geology-related career or careers have you held since graduating from USF?

________________________

*Write macros for SWFWMD to enter log data in a data management website*
Appendix C – Release Letter
June 18, 2016

To whomever it may concern,

I give permission to use my name in Alumni Narratives on Computational Geology (Spring 1997 – Fall 2013).

With kind regards,
Denis Voytenko