A LONGITUDINAL SURVEY OF EXPERIENTIAL FIELD-BASED LEARNING IN GEOLOGICAL SCIENCES AND GEOLOGICAL ENGINEERING (GS&GE) AT QUEEN'S UNIVERSITY USING STUDENT ASSESSMENT OF LEARNING GAINS (SALG)

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Challenges from North to South
Des défis du Nord au Sud

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ABSTRACT
Field-based learning, in site investigation and geological mapping, is essential to the education of geological engineers because it develops the habit of mind of integrating sparse, disparate observations into meaningful conceptual models and helps students transition from learner to expert. To investigate students' field experiences and learning gains, we initiated a long-term on-line survey of students in Years 2 to 4. The SALG instrument consists of 4 sections each using Likert-like items to assess gains in: 1) thinking and working like a geoengineer, 2) skills development, 3) confidence in fieldwork, and 4) changes in attitudes. Item scores show year-to-year increases indicating that students are progressing in developing skills and are moving from emerging to mastery of the learning outcomes.

RÉSUMÉ
L'apprentissage sur le terrain, lors d'études de sites et de modélisation géologique, est essentiel à la formation des ingénieurs géologues, car il développe l'habitude de la pensée à intégrer des observations éparses dans des modèles conceptuels significatifs et aide les étudiants à passer du stade de débutant à celui d'expert. Pour enquêter sur les expériences des étudiants sur le terrain et l'amélioration de l'apprentissage, nous avons lancé un sondage auprès des étudiants de la deuxième à la quatrième année. L'instrument SALG se compose de quatre sections, chacune utilisant des éléments de type Likert pour évaluer les gains dans les domaines suivants : 1) penser et travailler comme un géo-ingénieur, 2) le développement des compétences, 3) la confiance dans le travail de terrain, et 4) les changements dans les attitudes. Les résultats montrent une augmentation des pointages d'année en année, ce qui indique que les étudiants améliorent leur potentiel de développement des compétences et passent d'une capacité émergente à une pleine maîtrise de leur apprentissage.

1 INTRODUCTION

A basic tenet of professional programmes is that experiential learning is critical to practice. In the Department of Geological Sciences and Geological Engineering at Queen's University (GS&GE), experiential learning, especially field learning is foundational.

Experiential learning implies that the learners are not just developing an inventory of facts like bricks in a wall, but are learning and re-learning by doing and applying new knowledge and skills. Kolb (1984; terms in italics are taken from Mobb, 2015) described the cyclical nature of learning, that begins with 1) a "*concrete experience*" where learners do an action; moves to 2) "*reflective observation*" where learners, on their own or by interacting with team members consider what has been done; further develops through 3) "*abstract conceptualization*" where learners make sense of their learning; and culminates in 4) "*active experimentation*" where learners use the new learning in practice.

Similarly, Biggs and Collis (1982) identified that "as learning progresses it becomes more complex", and that as learners go through stages of meaning making, from the accumulation of seemingly random observations in the early stages, to the complex meaning making that results in a system or conceptualization. Fostaty-Young and Wilson (2000) used Biggs and Collis (1982) as the basis for their portable "ICE" method of assessment. "ICE" stands for: **I**deas, the building blocks of learning including basic skills, facts, vocabulary of the novice learner; **C**onnections, that occur when the learner is starting to assemble the bits of information and facts and skills into meaningful relationships, and Extensions, when a learner transitions to an expert, and is able to use their learning in new ways. "Portable" means that the system can be used for learners at all levels of formal education, and recognizes that all of us can be at any level of learning depending on the topic and our own experiences. ICE has become widely used at Queen's University, especially in the Faculty of Engineering and Applied Science.

Practicing GeoScientists and GeoEngineers have a shared understanding, taken to be self-evident, of the value of field learning (Petcovic et al., 2014). While few may be able to articulate theories of experiential learning or increasing complexity in meaning making, many will recognize the cycle of doing, reflecting, conceptualizing and experimentation, as integral to learning in the field. This is very similar to our definition of field learning which involves 1) close observation and measurement of field phenomena, 2) selection of crucial data, 3) updating of a conceptualization, and 4) planning the next phase of data acquisition in order to determine the situations and past processes that have lead to the engineering properties of associated rocks, structural features, and presence of water. We contend that undergraduate students learning to map and doing site investigation field-work experience the progression identified by Biggs and Collis (1982) and articulated by ICE (Fostaty-Young and Wilson, 2000). It follows that field mapping is much more than an inventory of rocks observed.

Queen's students seeking degrees in science and engineering in GS&GE begin the fall of Year 2 with GEOE/L 221 that covers 30 hours of field and 30 hours of laboratory work. This is followed by a 12 day, 10 hour a day spring field course, GEOE/L 300. These two key courses, have learning outcomes (LO) that are consistent with Kolb's (1984) theory, and similarly map to the Ontario Council of Academic Vice Presidents (OCAV) Undergraduate Degree Level Expectations (UDLES) (OCAV 2007) and the Graduate Attributes (GA) developed by the Canadian Engineering Accreditation Board (CEAB).

For example, in GEOE/L 221 students are required to demonstrate that they can use basic field techniques to make reliable and meaningful measurements of key geological and geotechnical parameters, that they can plan and conduct field investigations, and that they can begin demonstrating spatial and temporal reasoning at all scales in real time doing field work. GEOE/L 300 builds on these skills and expects that students will be able to demonstrate that they can plan, design, evaluate, implement, and optimize (i.e. revise-redesign) an evolving site investigation in the field. These course level learning outcomes are consistent with the framework for the program level learning outcomes which include the expectations that students will be able to 1) apply knowledge and skills to find, identify, assess, investigate, interpret and solve complex open-ended problems, 2) use appropriate methods and strategies, in the field and laboratory, to obtain data and knowledge, and 3) understand the limits of their own and others' knowledge, conceptualizations, models, data, and interpretations (GS&GE QuQaps 2014).

The goal of requiring LO, GA, and UDLES is to test whether students are indeed achieving these outcomes, and if not, develop new or improved learning tasks and materials to better help students achieve these outcomes. The research reported here grew out of the desire to evaluate students' perceptions of their mastery of concepts and skills of field learning specifically engineering site investigation and geological mapping with a view to continuous improvement. Undertaking to investigate the use of LO and field experiences in GeoScience education is consistent with work done by Manduca et al., (2004). Further, Mogk and Goodwin (2012) in their exhaustive review of learning in the field, call for "…quantitative, hypothesis-driven, testable studies based on controlled experiments and theory … to demonstrate learning gains afforded to students in this unique instructional setting."

Our hypothesis is that field-based learning, especially field mapping, is essential because it develops the habit of mind of integrating sparse, disparate observations into meaningful conceptual models and helps students transition from learner to expert.

2 METHODOLOGY

In order to test our hypothesis, a survey instrument titled "A Pilot Multi-year Survey of Student Field Learning Experiences: Learning Gains and Outcomes" was developed. The survey uses Queen's preferred survey platform. The initial set of questions was adapted from a survey of students' assessment of learning gains (SALG Instrument 16988 by Hunter et al., undated) during summer research in laboratories at University of Colorado, Boulder. SALG instruments, using a Likert-style scale, have been used by chemists and physicists to assess gains from undergraduate summer laboratory research projects. SALG instruments are especially useful in obtaining information to improve courses and programs (Seymour et al., 2000; Kuh, 2001; Falchikov and Boud, 1989). That there are similarities between field learning and laboratory learning made this adaptation appropriate.

The survey was further refined in consultation with the Queen's Centre for Teaching and Learning experts. All survey information is anonymous and voluntary. The survey questions and letters of information and consent were evaluated and passed by the Queen's General Research Ethics Board in 2014 and 2015.

The introductory page of the survey provided the following definitions.

"**Field work**": Any off-campus field work or field trip involving active participation and collection of geoengineering data either academic or job-related.

"**Mapping**": A process of making field observations of earth materials and features in space, typically the 2D surface of the Earth, incorporating those observations and features into a 3D conceptualization (or model) of the earth system, and from that conceptualization, identifying spatial **and** temporal relationships among components).

"**Gain**": A personal assessment of intellectual or professional development or improvement.

The survey has 6 question sections; Sections 1 and 6 ask for demographic information and ideas for improving the survey. Sections 2 to 5 ask students to assess their gain, wherein the 37 item statements were aligned with learning outcomes for the field programme.

Students were asked about their learning of specific skills in Sections 2 and 4 to gauge their abilities to undertake tasks. To investigate their disposition for learning, Sections 3 and 5 invited students to consider how comfortable and confident they are in making observations and discussing them with others, and confidence in the measurements they are making. A selection of the survey questions is given below in Table 1.

Table 1: Sixteen of the 37 survey statements (paraphrased to decrease length) from Sections 2 to 5. These statements were selected on the basis of our anticipating what might be of interest to a geotechnical engineering audience.

S2	How much did you gain in…
Item	Statement/ Question
1	Analyzing sparse data sets for patterns
2	Figuring out the next logical step
3	Formulating a geological question
7	Understanding the importance of safety, ethics
8	Understanding how field data are collected
10	Synthesizing data into complex models
S3	Gains in confidence and comfort
12	Comfort in discussing geological observations
13	Comfort in working collaboratively with others
15	Confidence in my ability to overcome obstacles
17	Confidence in conducting procedures in the field
S4	Gains in specific skills
18	Creating/ interpreting a geological maps/ sections
22	Defending an interpretation when asked question
27	Managing my time
S5	Attitudes and behaviours
32	Feel a part of the geoengineering community
33	Feel that field work is essential to my programme
35	Feel that I see myself differently

Students were asked to rate their learning gain on a Likert-like scale of 1 (corresponding to none) to 5 (corresponding to a great deal). An option of N/A meaning not applicable was also available.

The pilot survey was deployed in April 2014. Three cohorts were invited to participate: Year 2 students who had completed GEOE/L 221, Year 3 students who had completed both GEOL 221 and 300, and Year 4 students who had completed additional field work or field activities associated with other courses or design projects and theses. The responses were sorted into three cohorts. Item scores (from 1 to a possible 5) for individual student responses were summed to provide a total score out of 185 for Sections 2 to 5. Scores of "N/A" and incomplete responses were not included. Scores for each question were averaged for each of the three cohorts to provide a score between one and five for each item.

3 RESULTS

The response rate for the pilot study was ~20%, and overall, broadly representative of the three years, of the gender distribution among students and of the distribution of Science and Engineering students. In GS&GE the engineering students are approximately 2/3 of Years 2, 3 and 4 and are split approximately 50:50 male to female (Table 2). The high response rate for female engineering students in Years 3 and 4 (73%) may bias the results. Average time to completion was eight minutes.

Table 2: Demographics of the respondents. N = 42.

Year of study	Female %	Male %	Geo-Science %	GeoEn-gineering %
2	58	42	58	42
3 & 4	73	27	20	80

The median total scores, for all 37 statements, increase with year of study (Table 3) and differences in the range and interquartile range decrease. However, Mood's median test of the Year 2 and 3 results yields a probability of 0.5 suggesting that the difference is not statistically significant at a 95% confidence interval. A probability of 0.01 for the Year 3 and 4 median difference is significant.

The overall Cronbach's Alphas (Tavokol and Dennick, 2011) for responses from each year are >0.9 indicating that the reliability of the survey is high and that students were responding intentionally. Total scores for individuals correlate well with their written comments (which are not shown here).

Table 3: Statistics for Total Scores. The maximum score is 185.

Year	n	Median	Inter-quartile range	Min score	Max score	Cron-bachs' Alpha
4^{th}	17	171	24	126	183	0.94
3^{rd}	11	145	33	109	170	0.94
2^{nd}	10	120	51	89	177	0.98

Tables 4 to 7 show the summary statistics for responses to each section of the survey. In each section median scores increase with year of study and Year 2 to 3 differences are not statistically significant as indicated by Mood's median probability of 0.2.

Table 4: Statistics for Scores on Section 2: Application of knowledge. The maximum score in Section 2 is 50.

Year	n	Median	Inter-quartile range	Min score	Max score	Cron-bachs' Alpha
4^{th}	19	48	4	35	50	0.87
3^{rd}	11	42	8	33	48	0.81
2^{nd}	12	39	12.3	28	50	0.92

Respondents' reported gains in their confidence and comfort with field work show the same trend as application of knowledge (Tables 3 and 4). The difference between the minimum and maximum score decreases with increasing year, as does the interquartile range.

Table 5: Statistics for Scores on Section 3: Gains in confidence and comfort. The maximum score in Section 3 is 35.

Year	n	Median	Inter-quartile range	Min score	Max score	Cron-bachs' Alpha
4th	19	33	4	20	35	0.91
3rd	11	28	8	20	32	0.83
2nd	12	25	11	17	32	0.91

Similar patterns are seen for responses in Tables 6 and 7.

Table 6: Statistics for Scores in Section 4: Gains in specific skills. The maximum score in Section 4 is 50.

Year	n	Median	Inter-quartile range	Min score	Max score	Cron-bachs' Alpha
4th	17	46	8	37	50	0.73
3rd	11	36	9	27	47	0.81
2nd	11	32	11	26	48	0.87

Table 7: Statistics for Scores in Section 5: Attitudes and behaviours. The maximum score in Section 5 is 50.

Year	n	Median	Inter-quartile range	Min score	Max score	Cron-bachs' Alpha
4th	19	46	6	34	50	0.84
3rd	11	36	14	22	50	0.92
2nd	11	33	22	16	48	0.94

The overall Cronbach's Alphas–for each of the four question sections were 0.7 or greater, indicating that the reliability of the subsections of the survey is high and that students were answering questions intentionally.

The item scores and variances for selected queries listed in Table 1 are shown in Table 8 and discussed below.

Table 8: Mean item scores and variances for a selection of items as listed in Table 1, for respondents in each of Years 2, 3 and 4.

	Year 2		Year 3		Year 4	
Item	Item Score (5 max)	Variance	Item Score (5 max(	Variance	Item Score (5 max)	Variance
S2	Gains in application of knowledge.					
1	4.0	0.44	4.0	1.00	4.6	0.26
2	3.8	0.84	4.1	0.29	4.4	0.24
3	3.5	0.72	4.1	0.49	4.4	0.76
7	3.9	0.77	4.5	0.47	4.8	0.19
8	4.1	0.99	4.3	0.42	4.8	0.15
10	3.4	1.16	3.5	1.27	4.8	0.19
S3	Gains in confidence and comfort					
12	3.3	0.46	3.4	0.85	4.4	0.49
13	3.7	1.34	4.6	0.25	4.6	0.49
15	3.5	0.94	4.1	0.69	4.6	0.38
17	3.3	1.34	3.5	0.87	4.5	0.64
S4	Gains in specific skills					
18	4.1	0.77	4.1	0.89	4.5	0.64
22	2.6	1.82	3.5	1.27	4.4	0.51
27	3.7	1.12	4.2	0.96	4.5	0.26
S5	Attitudes and behaviours					
32	2.8	2.18	2.9	1.29	4.1	0.93
33	4.1	1.21	4.6	0.85	4.9	0.11
35	2.9	2.32	3.5	1.47	4.2	0.82

4 Discussion

The individual item scores for the three cohorts show a wide range of scores reflecting a variable progression of learning and personal development in the four sections of the survey.

For the results from students in Year 2, the item scores scores range from 2.6 to 4.1. The higher scores (e.g. Items 1, 8, 18, and 33) are associated with the mechanics of and confidence in the skills they have acquired doing 30 hours of field work in GEOE/L 221 in the fall of second year. These correspond to the "concrete experience" of Kolb (1984) and Ideas level learning of Fostaty-Young and Wilson (2000). Lower scores (e.g. Items 10, 12, 22, 29, and 30) are associated with understanding and comfort and confidence in interpreting their findings. This indicates that respondents are emerging as reflective observers only, and have not yet progressed to the abstract conceptualization stage (Kolb, 1984) or the Connections and Extensions as articulated by Fostaty-Young and Wilson (2000).

For the results from respondents in Year 3, the item scores range from 2.9 to 4.6. Higher scores (e.g. Items 7, 8, 13, 33) indicate that Year 3 students are mastering reflective observation and are appreciating the importance of experiential learning. Lower scores, which have the effect of lowering the median score for Year 3 respondents, (e.g. Items 10, 12, 22, 32) indicate that they are making reflective observations and moving towards abstract conceptualization and active experimentation of Kolb (1984) and the Connections and Extensions level of Fostaty-Young and Wilson (2000).

For the results from Year 4 respondents, the item scores range from 4.1 to 4.9. We interpret this to mean that they are confident in both the mechanics of field work, the data they collect, the interpretations the make, and in discussing their interpretations. The lowest scores are in questions 32 and 35, questions asking if they feel part of the GeoEngineering community and if they see themselves differently. Mogk and Goodwin (2012) suggest that seeing themselves as part of a community of GeoScience practice indicates a high level of learning gain, and such learning may need more time and experiences to develop, including post-undergraduate apprenticeships. All responses are greater than 4.1, and thus indicate that respondents are comfortable in active experimentation (Kolb, 1984), and are working at the Extensions level (Fostaty-Young and Wilson, 2000).

We attribute the higher median scores overall and in each subsection, to the work of Year 4 students in their capstone design courses and theses. These courses require a high level of data synthesis, conceptualization and design, and many involve field-work. Additional experiences, such as the fourth year field courses, independent projects, and summer employment after third year may assist students in developing their skills and confidence in skills. Anecdotally 4th year students report a very high level of satisfaction and learning during their design projects, and they report increased levels of confidence in their abilities to tackle complex, open-ended problems.

Most individual item scores show a year-to-year increase that we interpret as indicating a progression of the gains being made in field-work and site investigation. This is consistent with Ericsson's (2006) view of the importance of experience (or repetition) and deliberate practice, embedded in which is the notion of a guide for correction and provision of new learning tasks. Further Fostaty-Young and Wilson (2000) suggest that once learners become adept at basic skills (Ideas level), or the building blocks, the skills become internalized and can then be used in new ways (Extensions level). From the responses, it also appears that students need time to improve the basic skills of field-work (e.g. in GEOE/L 221) in order to use these skills for higher order learning and performance in solving more complex field problems (e.g. in GEOE/L 300 and more advanced field work, site investigation, and design).

The results agree qualitatively with our assessment of student learning gains, that is, that respondents are generally achieving the stated learning outcomes of their courses. However, the response rate was low and there is a potential for bias in the survey results as we have a high percentage of female engineering students in Years 3 and 4 who have responded to the survey. In addition, based on written comments, we think there may be a tendency for more successful rather than less successful students to undertake the survey.

Although our results may mean that our respondents are achieving the LOs and GAs as stated in our program, at this time, it would be inapt to extend the results to the entire undergraduate population in GS&GE.

5 Conclusions

5.1 The survey results show that SALG is a good method for surveying respondents' self-assessment of their learning gain in field-work.

5.2 The survey results show that the designed progression of learning and personal development over three years in the Queen's GS&GE programmes is occurring among the students who completed the survey.

5.3 The survey results agree qualitatively with our assessment of student learning gains, i.e., that respondents are generally achieving both course and program level learning outcomes.

5.4 The survey results indicate respondents appear to be moving from emerging to mastery in field learning.

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