INSTRUCTOR-STUDENT DYNAMICS MAPPING PROTOCOL DESIGN FOR A GEOMATICS ENGINEERING CLASSROOM

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ABSTRACT

The discipline of Geomatics Engineering evolved from Survey Engineering in response to the rapid development of technologies. Two University of Calgary courses, ENGO 343: Fundamentals of Surveying and ENGO 363: Estimation and Statistical Testing, are core courses taken by second-year Geomatics Engineering students, where they often have trouble grasping the content. Instructors restructured the courses to transition from a traditional lecture-centric classroom into an active learning environment. A longitudinal study was designed to map instructor-student dynamic in a classroom, using classroom behaviour to assess student learning. An independent third-party observed a given lecture by recording the actions of the instructor and students. The pilot was successful, and the study moved forward to Phase 2 in Winter 2019 using a revised observation protocol based on the Interactive-Constructive-Active-Passive (ICAP) Framework. lectures in ENGO 343 and ENGO 363, as well as lectures, labs, and tutorials for ENGG 407: Numerical Methods in Engineering were observed, where student and instructor actions at every 2-minute intervals were recorded using a list of pre-determined action codes. Different teaching styles inform the distribution of observed codes. Instructor must facilitate more active learning events, specifically Constructive and Interactive learning opportunities, to retain student engagement. The current protocol is revised to capture the complex student-student dynamics in a non-instructor-led classroom setting.

KEYWORDS

Geomatics Engineering, Classroom Mapping, Class Observation, ICAP Framework, Engineering Education, Active Learning, Standards 8, 11

INTRODUCTION

Geomatics engineering is the discipline specializing in the acquisition, modelling, analysis, and management of spatial data (*Geomatics Engineering*, n.d.). The discipline evolved from Survey Engineering as a response to the rapid advancements in engineering technology. As an accredited engineering program in Canada, all Geomatics engineering students must be able to demonstrate technical proficiency in the subject. Fundamental courses taught in second and third years ensure a strong technical and mathematical foundation for students, allowing them to explore advanced technical topics of their interest. Two of these second-year core courses are ENGO 343: Fundamentals of Surveying and ENGO 363: Estimation and

Statistical Testing. An additional mandatory mathematical course, ENGG 407: Numerical Methods in Engineering, while offered as a common core course by the school of engineering, is nonetheless taught by Geomatics professors.

These courses followed a traditional teaching approach for many years, where students copy notes as the lecturer presents, and the knowledge is cemented through fieldwork and programming-based lab assignments (Rangelova & Cao, 2019). In this learning framework, students' cognitive engagement is lower due to the limited opportunities for problem solving and discussions on open-ended questions. Also, students can struggle with the retention of fundamental engineering concepts as they move further into their studies (Rangelova et al., 2018).

The overall goal of this research is to assess student learning in the aforementioned courses, aligning with CDIO Standard 11: Learning Assessment. The research goal during phase 1 of the study was to determine the threshold concepts in the core geomatics engineering courses of ENGO 343 and ENGO 363. A threshold concept bottlenecks student learning, where a reconfiguration of the learning process is necessary to eliminate the bottleneck (Meyer & Land, 2003)(Meyer & Land, 2005). Examples of threshold concepts include random and systematic errors in data, univariate and multivariate data propagation, etc. Therefore, the main goal of phase 1 of the study was to identify these areas of troublesome knowledge (Rangelova et al., 2018). Phase 1 concluded that student cognitive engagement was higher when more problem solving and active learning were incorporated.

Following the conclusion of phase 1, instructors began incorporating more active learning into their lectures. Phase 2 was situated in the Interactive-Constructive-Active-Passive (ICAP) framework (Chi, 2009)(Chi & Wylie, 2014), as it provides the necessary contextualization for active learning in engineering (Streveler & Menekse, 2017). A new hybrid observation protocol, based on the ICAP framework, was used to assess both teaching and learning environment together with active learning (Rangelova & Cao, 2019). The goal of phase 2 is to determine how much classroom activities facilitate student's cognitive engagement at different levels of active learning.

BACKGROUND

As CDIO Standard 8, active learning is an instructional method that engages students in the learning process, requiring students to do meaningful activities and problem-solving while actively thinking about them (Prince, 2004)(*CDIO Standards 2.0*, n.d.). This contrasts with traditional lectures, where students passively receive information from the instruction. Active learning is characterized by student activity and engagement in the learning process. The benefits of active learning are evident from literature such as where students will remember more content if brief activities are introduced to the lecture, and that courses should promote collaborative and cooperative environments (Prince, 2004). Also, Freeman et al. (2014) show that active learning can increase student examination performance by half a letter grade on average and demonstrates a 35% decrease in failure rate compared to traditional learning methods.

The ICAP framework further contextualize students' cognitive engagement behaviours into four modes: Interactive, Constructive, Active, and Passive (Chi, 2009). In the Passive mode, students store information but make no effort to participate, and learning contains no active engagement with course material. Examples of Passive learning includes listening to instructor or talking to a peer during instructor explanation. The Active mode involves students integrating new information by connecting it to their prior knowledge. Examples of Active learning for students include taking notes or asking the instructor a question. Through reflection, re-evaluation of their knowledge connection, contrasting ideas and solutions, and inducing information, students can achieve the Constructive learning mode. Constructive learning includes suggesting a solution or discussing the outcome. Finally, the Interactive mode is achieved when students collaborate on a learning task while transitioning through the previous modes with their peers. Interactive learning examples include explaining their solution or presenting (Rangelova & Cao, 2019).

Context

The classroom observations took place in the winter term of 2019 for the two geomatics engineering courses (ENGO 343 and ENGO 363) and the spring intersession for one common core engineering course (ENGG 407) offered to students in most engineering programs. In 2018-2019, there were 154 undergraduate students enrolled in the geomatics engineering program. During the phase 2 of the observation period, 52 students were enrolled in ENGO 343, 54 were enrolled in ENGO 363, and 65 were enrolled in ENGG 407. Out of all students enrolled in ENGG 407, 13 students were in geomatics engineering.

METHODOLOGY

Classroom mapping was performed by a third-party observer, working independently of the instructor and students. The third-party observer is a recent Geomatics engineering graduate with background knowledge in the course content and an MSc student in engineering. Before the observations, the course instructor provided the observer with some basic information about the lecture, including the topic, learning goals, and criteria for success. The observer made notes of the classroom dynamics using the classroom observation protocol, initially adapted from the works by Arshavsky et al. (2012). The protocol began with lecture description, student attendance, start time, end time, and occurrences of lecture interruptions. To assess the learning environment, four categories were observed on a 4-point scale. These categories include geomatics engineering content, instruction and feedback, student cognitive engagement, and student behavioural engagement.

The core observation protocol was modified for phase 2 of the study, by adopting the ICAP framework for categorizing classroom behaviour. A list of teacher and student activities were introduced, alongside a list of matching 2-4 letter codes. Student activities were broken down into Passive, Active, Constructive, and Interactive categories. For example, teacher activity codes include TEX – explains a concept, TAQ – answers a question, etc. Student activities can include SL – listen to instructor's explanation (Passive), STN – take notes (Active), SSS – suggest a solution (Constructive), and SES – explain a solution (Interactive). The observation sheet includes the following fields:

- Time interval: duration of each observation, in minutes
- Codes: three observed action codes
- Task: the classroom activity during each observation
- % Class Engaged: the percentage of students that appeared to be cognitively engaged by the lecture

See Appendix A for the full observation protocol used.

Before the start of the lecture, the observer completed the metadata for the class observation, including the fields of:

- Course name
- Instructor name
- Observer name
- Date observed
- Location of lecture / lab / tutorial
- Number of students in attendance (The observer may update this field if students enter the class after observation starts)
- Observation start time / end time
- Was lecture / lab/tutorial interrupted?

The observer also made note of the lecture topic, learning goals, and criteria success.

The class observation began when the lecture starts. For every two-minute interval, three action codes are observed, the task was noted, and the percentage of class engaged was recorded. The three action codes note the most significant learning events from both teacher and students during the observation period, even if more than three action codes could have occurred. Periodically, the observer records comments of classroom activities, whether to generalize interesting classroom dynamics or to note the effectiveness and drawbacks of the observed teaching method.

The observation data is tabulated in spreadsheets for visualization and analysis using custom Python code. The following analysis was performed on each set of observed data from each course:

- Teaching and ICAP distribution of observed student codes
- Student engagement during class
- Time spent on each Teaching and ICAP categories
- Time spent on each student code observed

In addition to the observations, students completed two sets of self-assessments: a conceptual checklist of current chapter topics and an end-of-unit survey.

RESULTS AND FINDINGS

Three sets of classroom observations were made for each class of ENGO 343, ENGO 363, and ENGO 407, generalized in Table 1.

A comparative analysis of ENGO 343 and ENGO 363 will be performed, to evaluate the differences in the teaching approach between two instructors to the same group of second-year geomatics engineering students. ENGG 407 will be analysed separately to determine the difference in student cognitive engagement between lecture, lab assignment, and group quiz.

Table 1. Metadata of Observed Courses

Course	Date Observed	Learning Activity	Observation Duration (min)	Student Attendance
ENGO 343	March 18, 2019	Lecture	50	22
	March 20, 2019	Lecture	50	26
	March 25, 2019	Lecture	52	23
ENGO 363	March 20, 2019	Lecture	50	16
	March 25, 2019	Lecture	52	18
	March 27, 2019	Lecture	52	16
ENGG 407	May 15, 2019	Lecture	66	62
	May 16, 2019	Computer Lab Assignment	50	39
	May 22, 2019	Group Quiz	22	64

ENGO 343 and ENGO 363

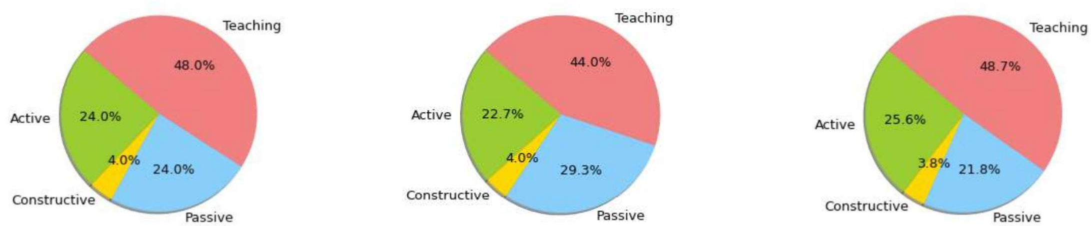

Figure 1. Teaching and ICAP distribution of ENGO 343 on March 18th (left), 20th (middle), 22nd (right)

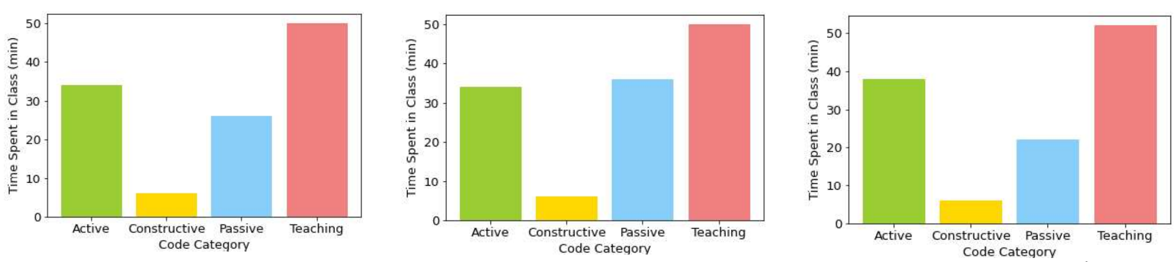

Figure 2. Time spent on Teaching and ICAP categories in ENGO 343 on March 18th (left), 20th (middle), 22nd (right)

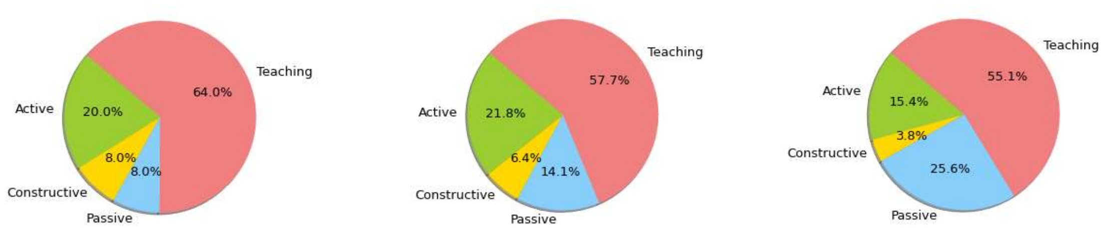

Figure 3. Teaching and ICAP distribution of ENGO 363 on March 20th (left), 25th (middle), 27th (right)

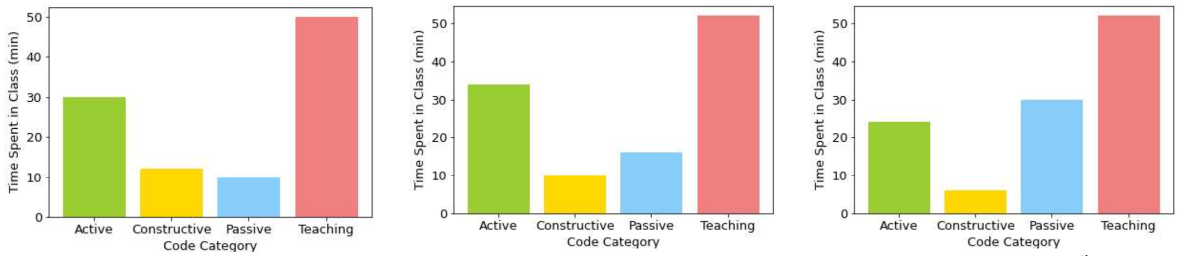

Figure 4. Time spent on Teaching and ICAP categories in ENGO 363 on March 20th (left), 25th (middle), 27th (right)

The distribution of Teaching and ICAP categories remains consistent across the three observed sessions in ENGO 343 (Figure 1). This figure compares the percentage of actions by the instructor (Teaching), and actions by the students (Passive, Active, and Constructive). Teaching occupied less than half of the observed codes, indicating that there were an equal amount of significant teaching events and student cognitive engagement events observed. On average, there is a similar amount of Active and Passive codes observed, but very little Constructive events occurred. Figure 2 quantizes these observed distributions into the number of minutes. Teaching occupied all 50 minutes of the lecture, which was the duration of the class itself. Active learning events were observed among some of the students for 30-40 minutes of the class. At the same time, Passive learning events were also observed for 80% to 90% of the students, for 20-30 minutes in the March 18th and 22nd lectures or for 30-40 minutes in the March 20 lecture. Constructive events were observed for less than 10 minutes in each lecture. The lectures in ENGO 343 offered a balance between teaching and student learning, but the learning still contained significant passive events. All three lectures covered 4 lessons in the topic of Route Surveying.

Compared to ENGO 343, the teaching events in ENGO 363 occupied more than half of all observed codes. In these lectures, the instructor was performing multiple significant events in many observations, and students demonstrated less cognitive engagement in comparison (Figure 3, 4). Students in ENGO 363 demonstrated slightly less Active learning, and slightly more Constructive learning in the March 20th and 25th lectures. However, the March 27th lecture yielded around 30 minutes of Passive events, significantly longer than the previous two lectures. The March 27th lecture was on the topic of Parametric Least Squares, where the instructor worked on an example by hand for the entire class duration. Observer comments noted that the lecture “pacing was slower than Monday’s [March 25th] lecture” and that “less student interaction than observed in prev. lectures”. Lectures on March 20th and 25th introduced and enforced a variety of topics in each lesson.

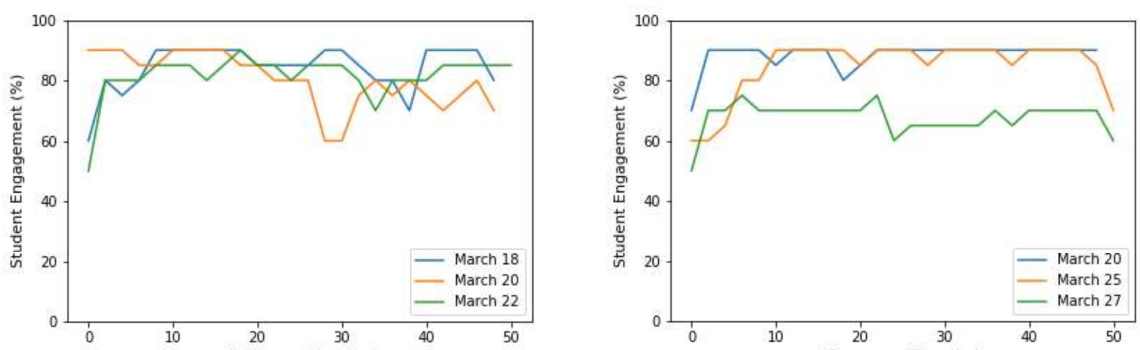

Figure 5. Student engagement in ENGO 343 (left) and ENGO 363 (right)

Seen in Figure 5, no lectures in both ENGO 343 and ENGO 363 managed to engage 100% of the students, as at least one student is always occupied with a non-related activity. In ENGO 343, student engagement falters immediately when the instructor is not directly engaging them with course material. Significant drops in attention occurs when the instructor is performing administrative work (making announcements and distributing documents), and when the students were asked to perform self-reflection on the topics covered in the previous lesson. It was observed that “student attention waivers when explaining long slides”. Comparatively, student attention remained consistent in the ENGO 363 lectures, as the instructor did not implement any student self-reflection. The March 27th lecture, as also noted earlier, had significantly lower engagement.

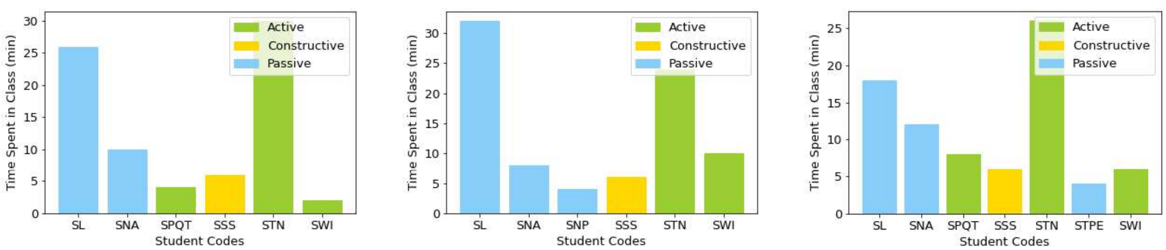

Figure 6. Time distribution of codes observed in students in ENGO 343 on March 18th (left), 20th (middle), 22nd (right)

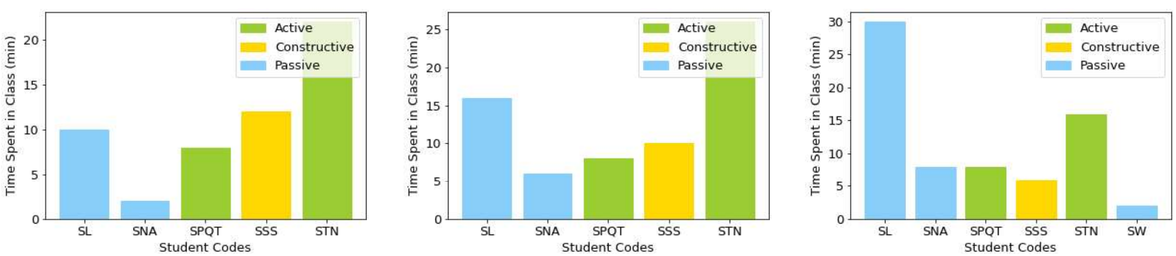

Figure 7. Time distribution of codes observed in students in ENGO 363 on March 20th (left), 25th (middle), 27th (right)

Figures 6 and 7 above break down the time-based distributions of each code observed for the student engagement, where:

- SL: listen to the instructor’s explanation (Passive)
- SW: idle / wait for the instructor (Passive)
- SNA: occupied with non-related activities (Passive)
- STPE: talk to a peer during explanation (Passive)
- SPQT: poses a question to the teacher (Active)
- STN: take notes (Active)
- SWI: work individually / reflect (Active)
- SSS: suggest a solution (Constructive)

In all lectures, the most predominant student activity observed were students taking notes (Active) and students listening to the instructor’s explanation (Passive). The only Constructive code observed was a student suggesting a solution when prompted by an instructor’s question. It should be noted that no Interactive codes were observed during both ENGO 343 and ENGO 363.

ENGG 407

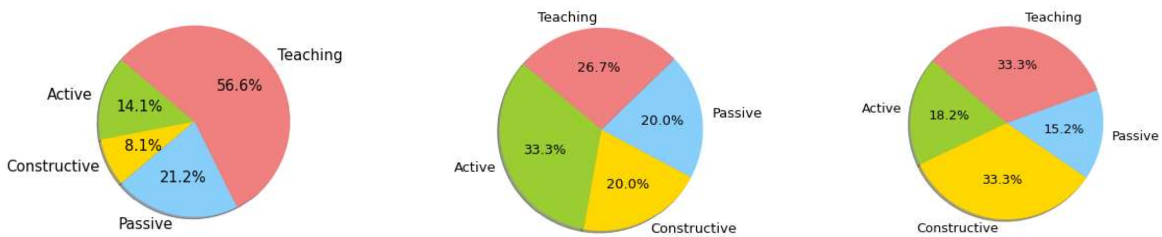

Figure 8. Teaching and ICAP distribution of ENGG 407 on May 15th lecture (left), 16th lab (middle), 22nd group quiz (right)

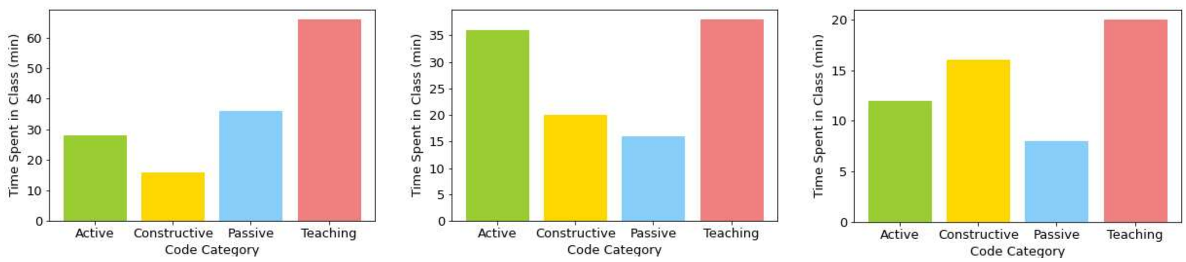

Figure 9. Time spent on Teaching and ICAP categories in ENGG 407 on May 15th lecture (left), 16th lab (middle), 22nd group quiz (right)

ENGG 407, taught by the same instructor as ENGO 363, saw a similar distribution of codes in the only lecture observed on May 15th (Figure 8). This reflects on the instructor's teaching style of performing more than one significant event for some observations. Both the lab assignment and the group quiz saw less teaching events, as the primary goal of the activities were to encourage collaborative problem solving. The time-wise distribution for the lecture (Figure 9) was comparable with observations in ENGO 363. Despite the larger percentage, Constructive learning occurred for a longer duration in the lab assignment as opposed to the group quiz.

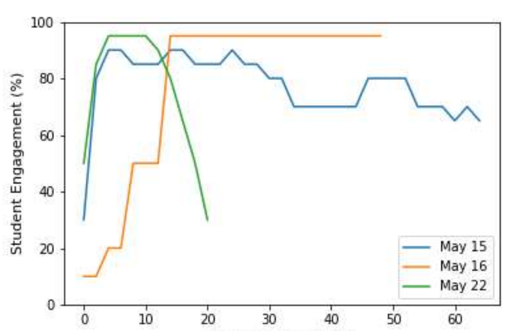

Figure 10. Student engagement in ENGG 407

Student engagement in the May 15th lecture saw a decline in cognitive engagement around 30 minutes into the lecture, following a period of high engagement. The decline corresponded to the beginning of an instructor-led coding tutorial, with observer comments being "not a lot of note-taking during tutorial". Comparatively, the lab session on May 16th reached a peak in the cognitive engagement as soon as the instructor concluded their explanation of the lab assignment. The group quiz on May 22nd showed a sharp decline in engagement as students finished their quiz.

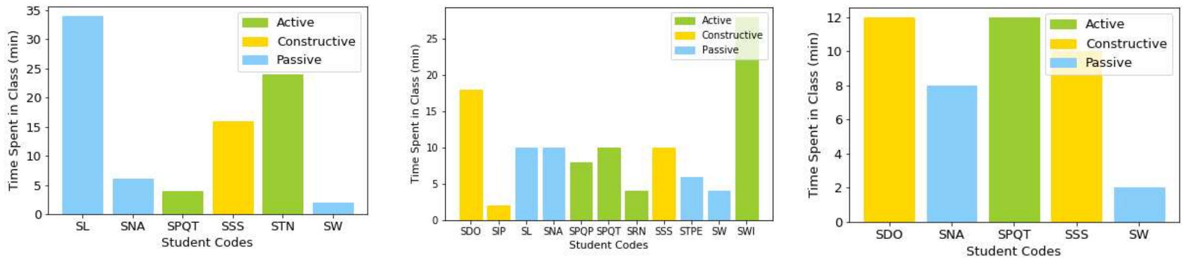

Figure 11. Time spent on each student code in ENGG 407 on May 15th lecture (left), 16th lab (middle), 22nd group quiz (right)

As per Figure 11, no additional codes were observed during the lecture, compared to ENGO 343 and ENGO 363. The primary Active learning activity during the lab session was students working individually on the assignment (SWI). The major Constructive code observed was student discussing outcomes amongst themselves (SDO). While a lot of codes were present, student activity observed was mainly focused on working individually, and using discussions with other students to support their learning. Additional codes observed during this session include:

- SPQP: pose a question to a peer (Active)
- SRN: read notes (Active)
- SDO: discuss outcome (Constructive)
- SIP: iterate a process/procedure (Constructive)

The group quiz observed mostly students discussing the quiz answers and asking the instructor for clarification on the questions. Just like ENGO 343 and ENGO 363, no Interactive activities were observed in ENGG 407.

RECOMMENDED CHANGES

Addendums and changes are recommended to the list of codes and observation protocol to:

1. Capture more complex student-to-student interactions during non-lecture class activities; and
2. Ease of recording for the observer.

The current observation protocol works well to capture the instructor-student dynamic in a lecture setting but fails to reflect the complexity of student-student interactions when they are working together on assignments and quizzes. The following codes are suggested to better understand student dynamic, especially for non-instructor-led activities:

- SNC: occupied with non-related coursework (Passive)
- SRA: research for an answer (Active)
- SPCT: pose a clarifying question/request to the teacher (Active)
- SIS: implementing a solution (Constructive)
- SBS: brainstorm solution (Constructive)
- SCP: collaborate to create a prototype (Interactive)

An additional "student disengaged" code is proposed to include where students are not learning, such as sleeping or leaving early. The observation data-sheet is modified to separate the codes between the teacher and student, as well as starting to track the number of students engaged, rather than tracking the percentage. The Table 2 below illustrates the new observation data sheet header:

Table 2. Proposed Update to Observation Data Sheet

<table>
<tr><th colspan="2">Observation Interval:
(min)</th><th colspan="4">Observation Codes</th><th rowspan="2">Number of students present</th><th rowspan="2">Number or % students engaged</th></tr>
<tr><th>Obs. No.</th><th>Observed Task</th><th colspan="2">Teacher</th><th colspan="2">Students</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Additionally, the student self-assessment is recommended to move to a mobile-friendly online survey form, to encourage anonymity and increase the response rate.
These changes will be implemented during phase 3 of the study, for ENGO 343 and ENGO 363 in the Winter 2020 semester.

CONCLUSION

This research performs a longitudinal study on second- and third-year geomatics engineering students by assessing their learning (CDIO Standard 11) in an active learning environment (CDIO Standard 8). Based on the feedback from its first iteration, geomatics engineering and core math classes were observed using action codes based on the ICAP framework. The instructor teaching style informs the distribution of codes, observing either an even split between Teaching and Student, as well as Active and Passive (ENGO 343), or more Teaching than Student events (ENGO 363 and ENGG 407). Decrease in student engagement corresponds to an increase in observed Passive actions, as well as when the instructor is not directly engaging them with course content. Classroom content must incorporate more active learning activities and consequently provide more Constructive and Interactive learning opportunities for students. The current protocol is not equipped to capture the complex student-student dynamic in non-lecture-based class activities, so therefore new codes and protocol is proposed for phase 3 of the study in Winter 2020.

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BIOGRAPHICAL INFORMATION

Sheng Lun (Christine) Cao is a second-year Master of Science student at the Schulich School of Engineering, University of Calgary. Her primary research field is in applied machine learning on urban planning and development. Due to her interest in Engineering Education, Christine also works as a research assistant for Dr Rangelova and Dr Detchev.

Elena Rangelova has a Doctor of Philosophy degree from the Department of Geomatics Engineering at the University of Calgary. She has been involved in research topics related to space-borne gravity, height systems, terrestrial water mass changes and satellite altimetry. She is an instructor in surveying in the Department of Geomatics Engineering and Schulich School of Engineering Chair in Innovative Teaching at the University of Calgary.

Ivan Detchev received his BScE (First Division) in geomatics engineering from the University of New Brunswick. Both his MSc and PhD degrees were in close range photogrammetry / digital imaging system and from the University of Calgary. His MSc thesis was on the 3D reconstruction of scoliotic torsos, and his PhD dissertation was related to image-based fine-scale infrastructure monitoring. He is currently a tenure-track instructor in surveying and mapping in the Department of Geomatics Engineering at the University of Calgary, where his research focus is transitioning towards engineering education / the scholarship of teaching and learning.

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APPENDIX A

Classroom Observation Protocol

Section 1: Meta Data

Course:
Instructor:
Observer:
Date:

Lecture: Lab: Tutorial:
Class arrangement:
Number of students in attendance:
Start time: End time:
Was lecture/lab/tutorial interrupted?

Topic:

Learning goals:

Criteria for success:

Most time spent on: (check on of the following objectives)

Conceptual knowledge	Introduced	Developed	Applied
Procedural knowledge	Introduced	Developed	Applied
Problem solving	Introduced	Developed	Applied
Inquiry learning	Introduced	Developed	Applied
Engineering Design	Introduced	Developed	Applied

Section 2: Codes

What the teachers does

TEX	explains a concept
TAQ	answers a question
TPQ	poses a question
TWB	writes on the board
TW	waits for students to finish
TMO	moves through the class and observes students
TDG	discusses with a group of students
TDC	discusses with the class
TC	draw a conclusion
TGA	assignes a group activity
TCA	assignes a class activity
TF	provides feedback to the class
TAD	performs administration work
TI1S	inreacts with one student

What students do

SL	listen to instructor's explanation	Passive
SW	idle/wait for the instructor	
STPE	talk to a peer during explanation	
SNP	do not participate in a group/class activity	
SNA	occupied with non-related activities	

STN	take notes	Active
SPQT	pose a question to the teacher	
SPQP	pose a question to a peer	
SWI	work individually/reflect	
SRN	read notes	

SDG	Draw a graph	Constructive
SSS	Suggest a solution	
SDP	Design a procedure	
SPE	Provide evidence	
SDO	Discuss outcome	
SCA	Choose alternative	
SIP	Iterate a process/procedure	
SR	Reflect on learning	

SEC	Explain a concept	Interactive
SES	Explain a solution	
SEP	Explain a procedure	
SPS	Provide a summary	
SRF	Respond to feedback	
SD	Debate	
SP	Present	

Section 3: Observation Data

TIME INTERVAL (min)		CODE	CODE	CODE	TASK	% Class Engaged
0	2					
2	4					
4	6					
6	8					
8	10					
10	12					
12	14					
14	16					
16	18					
18	20					
20	22					
22	24					
24	26					
26	28					
28	30					
30	32					
32	34					
34	36					
36	38					
38	40					
40	42					
42	44					
44	46					
46	48					
48	50					