

WIP: Decoding a Discipline – Toward Identifying Threshold Concepts in Geomatics Engineering

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WIP: Decoding a discipline – towards identifying threshold concepts in geomatics engineering

Abstract

This paper presents a teaching and learning study where one of the main goals is to identify threshold concepts in selected geomatics engineering courses. The paper first defines the term ‘threshold concept’ and lists a number of characteristics which make a certain concept a threshold one. A series of data collection methodologies such as formative minute papers and summative end-of-term surveys are proposed. Students in their second and third year of geomatics engineering registered in the courses under study are invited to participate. So far only one end-of-term survey, and a few minute papers on the introductory chapters for some of the courses have been conducted. While the end-of-term survey in its current state does not seem to be effective in identifying threshold concepts on its own, some of the minute papers have been able to pin point certain concepts as troublesome. This part of the project will be run for two years, so the authors will be seeking input from the engineering education community in order to improve the study in its second iteration.

Introduction

The research presented in this paper is part of a larger study related to deep learning of fundamental knowledge in geomatics engineering. On the hard-soft and pure-applied spectrums the discipline of geomatics engineering can be classified as hard and applied. This makes sustaining an environment for deep learning, as opposed to superficial learning, of core geomatics engineering knowledge a challenging task. This environment sometimes comes at the cost of instructors of higher level courses having to repeatedly review concepts taught in lower level courses. As a result, little time is left for tackling advanced learning outcomes. In order to mitigate this problem the authors would like to first 1) identify areas of threshold concepts in as many geomatics engineering courses as possible, then 2) develop extra tools or methods to address these threshold concepts, and eventually 3) observe any positive changes or improvements in students’ learning and knowledge retention. The authors are currently primarily focusing on the first task of the project, namely identifying the threshold concepts in geomatics engineering. This is the descriptive or ‘what is’ portion of the teaching and learning project. The next two paragraphs provide a brief introduction of the term ‘threshold concepts’, and a preliminary literature review of the research conducted on threshold concepts in science, technology, engineering, and mathematics (STEM) disciplines.

According to Meyer and Land [1] a threshold concept is something a learner cannot progress without. Baillie et al. [2] detail eight characteristics of threshold concepts:

- Liminality (the journey of crossing the threshold),
- Transformation (an epistemic shift),
- Integration (the sense of something “clicking together”),
- Reconstruction (an ontological shift),
- Irreversibility (the understanding of concepts cannot be undone),
- Boundedness (each concept explains a specific sub-domain of a discipline),
- Troublesomeness (concepts may be difficult), and

- Discourse (crossing the threshold yields proper use of disciplinary jargon).

The terms ‘threshold concepts’ and ‘troublesome knowledge’ are sometimes used interchangeably. Perkins [3] defined the idea of troublesome knowledge as knowledge that may be counterintuitive when first encountered. It should however be clarified that troublesomeness is one of the characteristics of threshold concepts, i.e., all threshold concepts are troublesome, but not all troublesome knowledge necessarily qualifies as a threshold concept. As per Cousin [4], liminality is the most critical characteristic of threshold concepts. Meyer et al. [5] portray liminality as the state of “being stuck”. The idea behind liminality was borrowed cross-disciplinarily from classic ethnography and anthropology. It was first introduced by Arnold van Gennep around 1919, and then further developed by Victor Turner in the 1960s [6], when describing the “rite of passage” during rituals. Meyer et al. [5] emphasize that in education students similarly travel through phases of pre-liminality, liminality, and post-liminality.

The study of threshold concepts has been deployed in a number of STEM disciplines. For example, concepts identified as threshold ones include ‘gravity’ in physics, ‘object-oriented programming’ in computer science, ‘uncertainty’ in environmental sciences [5], and ‘complex numbers’ in pure mathematics [1]. Within the wider engineering family, studies have been conducted in aerospace, chemical, civil, electrical, and mechanical engineering [7]. Srivastva [8] identified ‘map scale’, ‘datums’, and ‘data models’ as threshold concepts within the spatial sciences (i.e., geographic information systems, surveying, and remote sensing), where the subject area is similar to geomatics engineering.

The rest of the paper proposes methods to be used in exposing threshold concepts in a few geomatics engineering courses. Some preliminary results are then shown. As this is a work-in-progress, recommendations are suggested for future development of the project at the end of the paper.

Proposed methods

In terms of methodology for identifying threshold concepts in geomatics engineering, the authors planned/are planning a number of activities:

- In-class observations (where a research assistant observes a series of lectures in a particular class, and fills out a classroom observation protocol with categories such as content; instruction, student cognitive engagement, and student behavioural engagement with space for examples and comments under each category) [9];
- Individual or group think-aloud sessions (where a research assistant records students while they work on homework assignments or laboratory reports, and where the students are expected to verbalize out loud their thinking process);
- Self-reflections (similar to the individual think-aloud sessions but done in writing by the students as opposed to being recorded by the research assistant);
- Minute papers on muddiest concepts (where the students have a few minutes to answer the following question at the end of each course chapter: “Please identify one concept from chapter ... which you still find vague, difficult, not well-explained, or not well-understood. Why do you think this is?”; see Appendix A);

- End-of-term surveys (where at the end of the semester the students get to answer several questions for a particular course: e.g., how many lectures they have attended; how satisfied they are with the learning experience; what two topics they excelled at; what two topics they found particularly difficult; within the difficult topics, what specific concepts they found troublesome; and if the course instructor facilitated their learning experience with respect to these troublesome concepts; see Appendix B); and
- Analysis of exam grades (where the grades for specific exam questions are correlated to the threshold concepts pointed out by the students).

It should be noted that all activities are conducted in such a way that the students' identity is not compromised. For example, the research assistant is the person to transcribe the minute papers, think-aloud sessions, self-reflections, and end-of-term surveys. The instructors themselves do not have any information as to which students even participate in the study. This way, students are neither rewarded, nor penalized for helping out in the study.

Preliminary results

The courses under study in the threshold concepts identification part of this teaching and learning project include two second-year and two third-year geomatics engineering courses: ENGO 435 – Remote Sensing in the fall semester of 2017, and ENGO 343 – Fundamentals of Surveying, ENGO 361 – Least Squares Estimation, and ENGO 423 – Geodesy in the winter semester of 2018. As the study is still ongoing, and data is still being collected, what is included in this formative paper consists of a small sample from some of the activities listed in the proposed methods section. Namely, the results from the end-of-term survey for ENGO 435, the minute papers from two ENGO 361 chapters (i.e., “Introduction to the adjustment of observations”, and “Multivariate statistics and mathematical models”), and the minute papers from one ENGO 343 chapter (i.e., “Distance measurements”).

The response rate for the ENGO 435 end-of-term survey was 14/22 or 63.6%. Table 1 provides the details of the quantitative responses. From the students who filled out the survey 92.86% went to all or almost all lectures, and 78.57% were very satisfied or satisfied with their learning experience in the course. In addition, 42.86% of the participants thought that the instructor met their expectations in facilitating their learning experience in the areas of troublesome concepts to a great extent, and another 42.86% thought that the instructor did that to some extent. Upon looking into the outcomes, it would be highly recommended to introduce another level of response category called ‘To a satisfactory extent’ in case of the attribute of ‘instructor facilitation’. In terms of concepts that were well-understood vs. concepts that were troublesome the response was somewhat mixed (possibly due to the wide scope of the survey, i.e., an entire course). Two well-understood topics stood out: surface reflectance, and satellite properties and orbit calculations. However, reflectance/emissions was also listed as one of the predominantly troublesome concepts along with microwave remote sensing. In order to better identify troublesome concepts, and potentially classify some of them as threshold ones, minute papers are currently being run for the majority of chapters in the rest of the courses involved in the study.

The response rates for the muddiest concepts minute papers in ENGO 361 were 21/34 (61.8%) for the first chapter, and 20/34 (58.8%) for the second chapter. While once again some of the

responses varied, there definitely were trends that could be identified (possibly due to the narrower scope of the minute papers, i.e., a specific chapter from a course). In the first chapter the most troublesome concept was computing a weighted mean, while for the second chapter the most troublesome concept was by far identifying different types of functional models (i.e., direct vs. parametric vs. implicit). For the minute papers for the ENGO 343 chapter the response rate was 21/30 (70%). Here the distribution of the responses was bimodal. Some students identified precision and significant figures as troublesome concepts, while others identified errors (especially random error) and corrections.

Table 1. Summary of the quantitative responses for the end-of-term survey in ENGO 435

Attributes	% in each of the response categories
Attendance	All or almost all: 92.86%
	More than 50%: 0%
	Less than 50%: 7.14%
	No: 0%
	No response: 0%
Course satisfaction	Very satisfied: 35.71%
	Satisfied: 42.86%
	Somewhat satisfied: 14.29%
	Not satisfied: 7.14%
	No response: 0%
Instructor facilitation	To a great extent: 42.86%
	To some extent: 42.86%
	Not at all: 7.14%
	No response: 7.14%

Discussion

It is clear that an end-of-term survey on its own is not sufficient to identify threshold concepts for a given course. In one of the courses so far minute papers seem effective in identifying areas of troublesome knowledge, which is a prerequisite step in identifying threshold concepts. Of interest to the authors is what the timing should be for the minute papers. Should they be run in regular lecture time right after the theory for a certain chapter has been covered, or should they be run in a tutorial/lab session after either a laboratory exercise on the topic has been conducted and/or review problems have been solved? The authors assume that the combination of minute papers and an end-of-term survey for the same course, and the addition of one or two of the previously listed data collection methodologies would be complementary, and candidates for threshold concepts would be more clearly identifiable. Also, since troublesomeness is only one of the several characteristics of a threshold concept, mechanisms must be included to identify some of the remaining characteristics. For example, the end-of-term surveys may include questions related to the liminality, transformation, and integration aspects of particular concepts.

Concluding remarks

This paper presented results from an end-of-term survey and muddiest concepts minute papers related to three geomatics engineering courses. While the response rates so far have been relatively high (>50%), the study is still in its preliminary stage, and thus it is too early to confidently state threshold concepts affecting an entire course. At the end of the semester, when all data is collected, the authors will attempt to triangulate student responses to research assistant observations, and course grades/student performance on exams. The main goal for this paper is to get feedback from other academics in engineering who have conducted studies in teaching and learning. The authors are specifically interested in how to set up meaningful end-of-term surveys and detailed observation protocols, how to time minute papers, and in general what other activities or methods would work well in engineering classrooms.

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Appendix A: Minute papers



Thank you for taking time to write this minute paper. All answers are confidential. They will be used in the study *Towards Deep Learning of Core Geomatics Engineering Knowledge*. By providing your input and handing in this paper you grant permission to have your answers included in the study. You may decline to participate. You will not be penalized for this and your decision will not affect in any way your marks and end-of-term grade. Please be as truthful with your answer as possible. In order to protect your anonymity, we strongly advise you to hand in a blank paper if you decline to participate in this activity.

Please identify one concept from chapter which you still find vague, difficult, not well-explained, or not well-understood. Why do you think this is?

Thank you for providing your input. Please contact Dr. [redacted] if you have questions or concerns related to this paper at [redacted] or [redacted].

Appendix B: End-of-term surveys



Thank you for taking time to fill in this end-of-term survey on your learning experience in this course. The survey consists of 9 questions. All answers are confidential. They will be used in the study *Towards Deep Learning of Core Geomatics Engineering Knowledge*. By filling and handing in this survey you grant permission to have your answers included in the study. You may decline to answer any or all questions. Your decision will not affect in any way your end-of-term grade. Please be as truthful with your answers as possible. In order to protect your anonymity, we strongly advise you to hand in a blank survey if you decline to participate in this activity.

1. Please choose one of the courses listed below.

- ENGO 361* *ENGO 343* *ENGO 435* *ENGO 423*

2. Have you attended the lectures and labs/tutorials in this course? Please choose one answer.

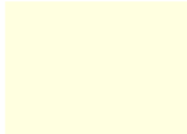
- All or almost all* *More than 50%* *Less than 50%* *No*

3. How satisfied are you with your learning experience in this course? Please choose one answer.

- Very satisfied* *Satisfied* *Somewhat satisfied* *Not satisfied*

4. Can you identify two topics in this course that you excelled at? A topic can be a chapter or unit from the course.

5. Can you identify two topics in this course, in which you experienced significant difficulties in understanding, interpreting, and/or retaining the course material?



6. Related to question 5, can you provide examples of concepts from a topic that were troublesome to you? You can identify a concept as troublesome if (a) you spent more time to learn that particular concept than the time you typically spent to learn other concepts, and/or (b) you could not relate that particular concept to other concepts in the topic, and/or (c) mathematics/physics equations were very difficult to understand, and/or (d) you did not have the prerequisite knowledge. Please explain.

7. Related to question 6, did the course instructor meet your expectations in facilitating your learning experience in the troublesome concepts?

- To a great extent* *To some extent* *Not at all*

8. If you answered positively in question 7, can you explain briefly how you benefited from the instructor's facilitation in terms of your learning experience?

9. Can you provide one or two recommendations related to the facilitation of student learning in this course?

Thank you for participating in this survey. If you have comments or questions please contact Dr. [redacted] at [redacted] or [redacted]