6:e Utvecklingskonferensen för Sveriges ingenjörsutbildningar, Chalmers tekniska högskola,
22 november – 23 november 2017

Internalising a threshold concept - what languages and channels are called for?

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***Abstract*—We offer an example from Chalmers university of technology of how the landscape of English-medium instruction (EMI) might enable or hinder enhanced learning of crucial aspects like a threshold concept (TC) in an educational programme. The study is part of a larger 3-year study focussed on observing EMI-learning contexts to investigate whether or not the hypothesis of incidental language proficiency holds. The main focus of this pilot-level sub-project is to study how talk about specific threshold concepts and the degree of content expertise are reflected in student conversations. Both quantative analysis and qualitative analysis by the disciplinary faculty suggest that the two threshold concepts studied are not mastered as well as the faculty have assumed. The pilot study has resulted in revision of course design and exaplanatory models.**

***Index Terms*—Discourse dimension, reactive power, threshold concepts, work curves**

I. Introduction

As English-Medium Instruction (EMI) increases world-wide, there appears to be a questionable assumption of the positive effects of immersion (Cf. [1] on mere immersion for ESP). While there are degrees of EMI[1], where some programs offer significant amounts of support for students and their language development [2], the most common situation still seems to be one where educators rely heavily on immersion. So, students are expected to study in English and reach a level of academic literacy in English (cf. [3] - [5]), but do so incidentally via content-oriented instruction only. Thus, in the case of vocabulary knowledge, through their "immersion" in an EMI-environment, students are assumed to pick up English words automatically and effortlessly [6].

At least in a European context, the majority of EMI-programs are found at the master's level and the vast majority of the students in such educational settings, not only overseas students, use English not as their first but rather as their second language or as a foreign language (ESL, EFL). Despite this language context, students face academic tasks that require advanced English-language use for reading, listening, speaking, and writing on a daily basis. In addition to international language tests for entrance into higher education, we rely on a shared 6-level language-proficiency assessment grid establish by the European council [7]. Assessment issues aside, CEFR-requirements themselves are problematic or inconsistent in that students are expected to do tasks that require levels 5 or 6 but are often accepted on level 4. So, again, the generous interpretation is the assumption of language proficiency development through self-regulated learning on English for a specific in a language context that is not an inner-circle one [8].

With this background, a team of colleagues at Swedish universities have set out to study this assumption of language proficiency development without instruction in EMI-settings. The PROFiLE project is a three-year longitudinal study of English-medium master's programs at Swedish universities, funded by the Swedish research council and carried out by three collaborating universities (Linnaeus University, Chalmers University of Technology and Stockholm University). The overarching purpose is to study students' development of academic literacy in English and relate the results to the needs of the prospective workplace. The overall research objective for the project, therefore, is to study the actual impact of English medium instruction (EMI) on English proficiency during the education and in the workplace. In short, is there or what is the incidental English academic and professional language acquisition in EMI?

The project comprises many sub-projects or studies but the general hypotheses that inform the design of studies can be summed up as:

> *Hypothesis 1*: On the assumption that students are challenged by the use of English for academic purposes, students are likely to have a relatively limited productive English repertoire and will need time before they are able to use English effectively in academic (or professional/disciplinary) contexts.
> *Hypothesis 2*: On the assumption that studying in an EMI-context is beneficial to students' development of English for academic (and professional/disciplinary) purposes, (because it presents opportunities to engage with academic English and learn English incidentally), students' production in Year 2 (as compared to Year 1) ought to be more advanced or more effective and/or indicate that students are using English in a more sophisticated way.

Manuscript received October 5, 2017. This work was supported by The Swedish Research Council (grant number 2013-2373).

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[1] (*Useful article on EMI and Content and Language Integrated Learning (CLIL) in Europe: Coleman, James A. (2006). "English-medium Teaching in European Higher Education." Language Teaching 39 (1).1–14.*
And a more recent one on the complex framework around EMI in Europe: Dafouz, E. and Smit, U. (2014). Towards a dynamic conceptual framework for English-medium education in multilingual university settings, Applied Linguistics. doi:10.1093/applin/amu034)

Aside from the hypotheses, the various sub-projects in PROFiLE also share or contribute to the project's triangulation of data. We aim to triangulate three types of data, and data collection methods in our related investigations.

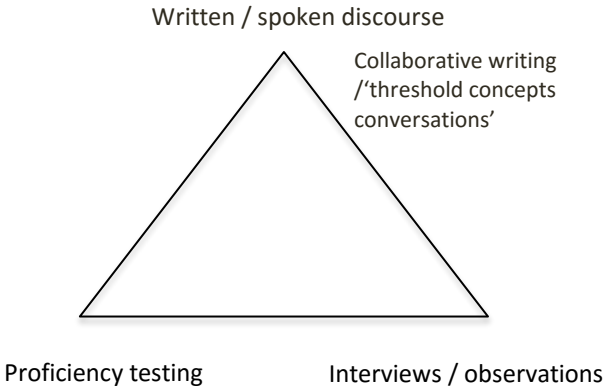

Figure 1. Main triangulation dimensions of PROFiLE

The focus of the current paper, however, is on a small sub-project and its piloting of a study to investigate the spoken disciplinary discourse of the students in the project. This sub-project in PROFILE investigates how and to what extent students' conversations about threshold concepts in their discipline can be used as indicators of professional and disciplinary discourse literacy. So, while the underlying research question is too far-reaching for any one isolated study - 'What is the relationship between content knowledge and disciplinary discourse literacy?' - the PROFiLE project needs to take some small step in the direction of studying spoken disciplinary discourse. The questions informing this paper, include basic issues for pilot studies like:

> *What are the preferable ways of collecting data that enables such a study?*
> *How should the data be analysed?*
> *What does it, or would it, actually measure?*

In view of other activities in the project and the staffing resources for the project, there are some options. It might be possible to observe and document disciplinary discourse while observing lab work between students or possibly during supervision sessions with tutors. Such situations would be 'quasi-naturalistic' but hardly contexts that could be replicated in the workplace. Although our current pilot direction is less natural as conversations go, we hope it has the potential of capturing students' disciplinary discourse by involving them in a conversation about a threshold concept.

II. The Threshold Concept Framework and Discourse

The notion of threshold concepts was first articulated in 2003 by Ray Land and Jan Meyer in a UK education development project 'Enhancing teaching-learning environments in undergraduate courses' [9]. It draws, however, on earlier work in the area of constructivism and the idea of troublesome knowledge [10]. In the initial Land-Meyer formulation, threshold concepts were said to be characterized by being 'transformative'; 'irreversible'; 'integrative'; 'bounded'; and 'troublesome' [9] Since this formulation of the idea, additional characteristics have been added, and the list now also includes: 'recursive'; 'reconstitutive'; and 'liminal' (Cf. [11]).

While it would be counter-intuitive to compartmentalise the characteristics of threshold concepts, all aspects interact, it is precisely the element of a discursive dimension for threshold concepts that is of interest for this study. However, not much seems to have been said about this discursive dimension. Barring studies of grammar and programming, most of the studies listed for instance on the important 'threshold concepts site' – do not appear to be addressing the elusive discursive dimension other than in passing. In a 2005 paper, Meyer and Land emphasize the "inter-relatedness of the learner's identity with thinking and language" [12]. They go on to claim that threshold concepts "lead not only to transformed thought but to a transfiguration of identity and adoption of an extended discourse" [12]. This transformative element, including its discursive component, is also highlighted in educational frameworks like 'academic literacies [4] and Barrie's model for graduate profiles [13]. Interestingly, it is this discursive component of troublesome learning that poses challenges for Biggs' educational application of constructivism – 'constructive alignment' [12]. There are difficulties for lecturers' in aligning teaching and learning activities and assessing them when the the discursive challenges facing students even at a terminological level might go unnoticed in the design of an activity.

III. Method

At Chalmers, all graduate-level education uses English as the medium of instruction. The university has approximately 11,000 students, 2,700 of whom are enrolled on one of 41 masters programs. In the project, we work with two MSc programs at the university: MSc in Electrical Power Engineering; MSc in Structural Engineering and Building Physics.

The procedure for the sub-project has been to interview lecturers in the two programs and isolate tentatively interesting bottlenecks of understanding in the engineering courses and then analyze to what extent these bottlenecks might involve threshold concepts. This process is informed by Middendorf and Pace's suggested approach for 'decoding the disciplines'[14]. The process has involved several meetings and lecturer's attempts at explaining the threshold concepts. In order to prepare lecturers prior to our first conversations, they have been offered a short two-page introduction to threshold concepts [15].

Once a threshold concept has been isolated, we have designed a prompt for it to generate a discussion between two students. For the students in electrical power engineering, we work with the threshold concept of 'reactive power' (Cf. [16] for the concept addressed as a threshold concept; Cf. [17]for an in-field account of the concept). For the structural engineering students, we have identified 'working curves and the

constitutive relationship' (strain and stress distribution and its effects on different materials basically) as one threshold concept and for the building physics dimension of the program we have identified 'the thermal inertia of buildings' as a bottleneck but have not quite isolated the threshold concept(s) it might comprise.

Documenting student conversations

For the pilot stage of the project, fourteen conversations have so far been recorded and transcribed. They all last approximately 15-20 minutes and involve 12 students in courses at the Electrical power engineering program and the threshold concept 'reactive power'. For Structural Engineering, we have recorded 14 students talking about 'work curves of steel and concrete'. We have recruited students by visiting the courses where the lecturers we have interviewed have welcomed us. One 'conversation' in electrical engineering ended up effectively being a think-aloud protocol (TAP) as the conversation partner failed to show up. We decided to proceed with the material anyway since it would provide useful information to find out to what extent the prompts also work for TAPs.

IV. Tentative results

Based on the pilot conversations recorded since 2015 with students from the two MSc programmes, a number of observations can be made based on the joint analysis. From a quantitative point of view, the prompts generated on-topic conversations where significant disciplinary clusters of words where used. It is also possible to distinguish between conversations based on the frequency and ranking of the word clusters they use. Looking at clusters, there is also a difference between first year conversations and second year conversations. Having said this, the corpus of spoken English the conversation has generated is far too small to say anything confidently of course.

Table 1. Top 10 information-oriented clusters of 2-4 words in the MPEPO corpus for 'reactive power'. Parenthetical information indicates rank and frequency of the units in the total output of each group, respectively [22].

Rank	Year 1 (5 students)	Year 2 (8 students)
1	reactive power (7/69)	reactive power (1/66)
2	surge impedance (32/26)	transmission line (5/32)
3	impedance loading (49/19)	shunt capacitor (9/23)
4	surge impedance loading (51/19)	shunt inductor (16/20)
5	transmission line (59/17)	transmission system (30/16)
6	receiving end (109/11)	power compensation (33/14)
7	shunt capacitor (11/11)	reactive power compensation (38/13)
8	tap changers (121/10)	generate reactive power (78/8)
9	power compensation (166/8)	lightly loaded (85/8)
10	power transmission (167/8)	power flow (87/8)

Counts like these are superficial. However, from an electrical power engineering perspective, it is nevertheless surprising to note that 'surge impedance' is missing from year 2. The alternative cluster would have been 'characterstic impedance' which does occur and is mentioned 6 times in two of the year 2 conversations and ranks at 15 among the information clusters. An individual observation here is that the one student who has taken the conversation both in year 1 and in year 2 reflects this exact change. He uses surge impedance in year 1 and characteristic impedance in year 2.

Table 2. Top 10 information-oriented clusters of 2-4 words in the MPSEB corpus for 'work curves'. Parenthetical information indicates rank and frequency of the units in the total output of each group, respectively [22].

Rank	Year 1 (6 students)	Year 2 (8 students)
1	normal force (36/12)	stress distribution (19/20)
2	reinforced concrete (73/8)	cross-section (23/18)
3	concrete section (82/7)	normal force (36/15)
4	pre-stress (92/7)	concrete beam (60/11)
5	in compression (112/6)	Bending moment (72/10)
6	stress distribution (125/6)	stress and strain (77/10)
7	compressive normal force (147/5)	strain distribution (94/8)
8	concrete and steel (148/5)	force couple (104/7)
9	cracked section (150/5)	distribution change (136/6)
10	steel section (173/5)	reinforced concrete (190/5)

For the differences between the two years in the MPSEB-programme, it seems possible to say that that the second year students appear to have a higher frequency of content related clusters. The fact that both 'stress distribution' and 'strain distribution' appear as well as the 'distribution change' suggest that they have been on topic and with a higher frequency than the first years. The differences might indicate that the second year students are less hesitant.

However, this basic quantitative analysis risks being flawed, and might at first glance show us something that is not really there. Mere use of words need not imply understanding of course. So, what does this look like with a more qualitative approach, and what would indicate understanding?

The transcripts have been jointly analysed and the interpretation of the electrical power engineering and the structural engineering lecturers is crucial for the qualitative

analysis. One of the 'reactive power' conversations offers two passages of interest where challenges are highlighted:

Excerpt 1 – first year students:

> **Student 1**: "depending on the purpose. For example if it's a step-up transformers, if you step up the voltage, you step up the current. But loading means like you are changing the loads that you control. Like for example our houses – you're applying more circuits, or more tv:s .. or stuff like that."
>
> **Lecturer comment about the passage**: "If the voltage is stepped up, the current is reduced. In this way, the transformer keeps the power more or less the same on both sides. It could be misunderstanding or uncareful speaking, or both."

Excerpt 2 – first year students:

> **Student 2**: "Aha, ok. So, in general for a high power line it is not so sure that it is gonna consume reactive power but for a low power line then it usually consumes reactive power, or?"
> **Student 1**: "I think both of them, they consume reactive power."
>
> **Lecturer comment about the passage**: Normally in a 400 kV the line generates more reactive power than it consumes; whereas in 130 kV, it is the opposite. That is why in 400 kV, we usually have shunt reactors to consume excessive reactive power generated by the lines, and in 130 kV, we use shunt capacitors to compensate reactive power consumed by the lines.

What we believe we see in the two excerpts is that in excerpt 1, the lecturer is not sure about the level of understanding reflected in the conversation, whereas in the second excerpt, there is a mistake that the lecturer can pinpoint. The phrase 'uncareful speaking' is a particularly interesting one in this context of the discursive dimension of threshold concepts. With this phrase, the lecturer highlights how the discursive expectation is not met in the isolated passage.

Needless to say, it is tempting to jump to the conclusion that there is lacking understanding, but the lecturer does not do that. What is possibly one of the most interesting findings in the pilot material is also the most frustrating. The impulse to interpret fluency and correct terminology as effective and reflective of understanding is one that must be resisted in this analysis. It would seem reasonable to consider this challenge also for the quantitative material.

For the conversations on 'work curves', similar passages can be found. However, here we have also noted an additional dimension affecting the conversations – the structural engineering lecturer believes digression and false starts in the conversations are indicative of students forgetting the basics as they take the more advanced courses and therefore fail to articulate sufficient understanding of the concept.

Excerpt 3 – first year student:

> I .. I.. have made calculations on eh the strength of of wood when you're compressing an 'actual' [?] and eh bending it and all that in order to to be positive about the structure will work, you gotta fulfill - I think it's this equation. The stress in bending over the strength in bending, and now we're talking about wood, which is actually not the task but eh [laughter] but there is something , there is something to this at least. So, the stress in a bending over the strength in bending plus the strength in actual compression over the strength in actual compression. Eh, and then you got some factor here Kc I think that gotta be lower than one. If that's the case. you know your structure works.
>
> **Lecturer comment about the passage**: These are words that would be used in this context but they don't mean anything. He falls back on what he knows but doesn't answer the question.

Excerpt 4 – second year students:

> **Student 1**: Yeah, we have like a wind load or something [mm, yeah] acting on the [yeah] the column. Eh ... so... then we have a cross section eh [drawing] like this eh a normal force and we have a bending moment ... yeah, what's happened is that we have eh N here, if it's ehm eh, ehm if it's acting in the middle here, it doesn't influence anything but often, or many case, we have a [with the centricity] yeah, exactly. We [yeah] have a distance here from the ... eh ... from the midpoint so to say where we calculate the moment from. So then we will get bigger moment so to say there in the cross-section [right] cause the n-force, or the normal force, will increase the moments [yeah] You understand? [that makes sense] So, this force and this force, will both eh contribute to the bigger moment in the cross-section [right, right]. So this M rd has to be bigger to [yeah] contribute, to ...to keep the column state
> **Student 2**: Yeah, but also I ... when we have a normal force, I remember that when you do like post-tensioning or pre-tensioning, [yeah?] you [I don't remember that] [laughter] you out like a compression in the beam [yeah] so that you don't get tension [yeah] and don't get cracks as early because you like you don't have any [force on it, no] No yeah. But then you also have this effects where you get the external [the normal, yeah] moment and also buckling and...
>
> **Lecturer comment about the passage**: In this section they are out of control. They have fragments of a explanation but they have problems to put it together and they mix in newly gained knowledge that makes it more difficult for them to explain the answer to the question.
>
> The main mistake and that surprises me that they don't go back to the already known and agreed drawing of the section. And, start from this in order to reach to common explanation of how this changes.

While excerpts 3 and 4 are indicative of students who struggle to discuss the prompt and fail to convince the lecturer that understanding is communicated, there are also 'work curve' conversations where the lecturer can tell, within 30 seconds of listening and reviewing the sketches, that students have sufficient ownership of the content discussed.

V. Discussion – Methodological challenges

First of all, there are no results proper. Only seven conversations have been recorded and transcribed in each programme. The analysis that has so far been performed is superficial at best. More importantly, from the perspective of PROFiLE research questions, it is not possible to say anything with much realibility in terms of comparing student performance in year 1 with that of year 2 (hypothesis of progression during program). Nor have any professionals in industry been asked to pursue the conversation (hypothesis of development of context adaptations).

The focus of the test is to try to establish to what extent the students' spoken English can be said to be reflecting disciplinary discourse. Such a focus and aim present challenges: What what is to be the unit of analysis? What actually reflects such discourse? And what would the students' discourse during the conversation actually reflect?

Any corpus tool can be used to extract the vocabulary profile of the discourse. Yet, that risks being frustratingly misguiding. The disciplinary lecturers are at times unable to tell whether or not students express understanding even if they technically use the expected terms.

An analysis of the argumentative development of the conversation seems more rewarding but, as it turns out, might suffer the same challenge of interpreting language use. An additional methodological aspect of the argumentative analysis is that is appears to require the engineering lecturers' involvement throughout the process and that is not always possible (in the PROFiLE project).

The nature of the conversations is such that while visualisation might not be required, engineering students find it quite natural to turn to sketching or some whiteboard schematics. The procedure has involved asking for permission to record audio or video, but students so far has preferred only audio. There is some reluctance to appear in video recordings. While our focus is the discourse and the spoken aspects of it, and while we do document sketches and whiteboard products, the many deictic elements in the conversations suggest that the added analytical perspective of having access to a video recording would be beneficial.

Finally, from an assessment point of view, the analysis might focus on to what extent the students arrive at the correct answer to the prompts. Such result or product orientation, however, does not guarantee capturing the discursive elements of the exchange. Needless to say, from the perspective of engineering education research, the lecturers are more interested in hearing the students making 'correct' statements and the language dimension is obviously central to assessing that but from a linguistic-cum-discursive perspective, this type of focus has also highlighted the challenge of what might almost be referred to as 'interrater reliability'. In other words, a linguistic approach might be misleading in terms of capturing or identifying statements indicative of learning or understanding. Fluency and the presence of correct terminology does not necessarily reflect understanding.

Second order difficulties with this study involve the tension between research approaches and educational development philosophy. The overall PROFiLE study is an observational one rather than an action research one, but these conversations and the lecturers' involvement in defining threshold concepts as well as in analysing the data gives rise to improved learning activities in their courses; thus, potentially affecting the results of the observational study. Yet, we are really only welcome into the programs on the assumption that we will feedback advice for course and program revision; the question, then, becomes one of how long that can wait until it becomes ludicrous.

Having said all that, some observations can still be made. To begin with, the conversation prompts for 'reactive power' and 'work curves' work. They generate dialogues (or a TAP) that allow documenting the discourse students use to explain the phenomena. From a learning perspective, the prompts work also in terms of collaborative learning as there are instances in the material where students gradually refine their understanding during the conversations. The prompts also appear to allow engineering faculty to distinguish between students' levels of understanding.

However, even if the prompts generate a profile of the speakers' discourse about the threshold concepts and their joint efforts, it is still not obvious how to approach the data. What, in fact, would this kind of conversational or think-aloud data really tell us about the disciplinary discursive literacy of the students? In other studies that are part of the PROFiLE-project (Malmström, Pecorari & Gustafsson, 2016), it is reasonable to analyse data on the assumptions that vocabulary reflects proficiency and enables communication and comprehension (Staehr 2008; Milton 2010; Laufer & Nation 1999). In this study, however, which needs to combine a linguistic approach with a concern with disciplinary knowledge, such assumptions are less readily met. Rather, the lecturers' inability to tell sloppy communication from misunderstanding in some cases seems indicative of the opposite.

From a disciplinary content mastery perspective, however, the results are even more problematic if they are representative of student learning on the programmes. The student performance in the conversations suggests, for instance, that the programme design's alleged alignment is questionable since there is no secondary assessment point for programme learning outcomes prior to the handover to the MSc-level. This gap in assessment also means that there is an obvious risk MSc-programme managers design programmes on flawed assumptions. A final aspect of the results is that the programmes may have to decide what languages are sufficient in assessment contexts for threshold concepts as mathematical articulation of the conceptual understanding is insufficient or possibly hard to internalize.

VI. Future research

There is some comfort in knowing that we still have more data to collect before we can tell to what extent this threshold concept conversation prompt really allows us to study what we need to study. On a simple assessment level, we need to compare exam results at a student-by-student level. There have been individual instances where the lecturers have 'recognised' a student as a particularly strong student or a student who struggled on courses for instance. There is also the need to record the 'students' once they have arrived at the workplace. Here, lecturers have mentioned that the prompts would work well in job interviews for instance. Once we have those additional building blocks of the study, it might be easier to develop or adjust analytical methods for the data.

Ona different note, the conversations have lead lecturers to revise their courses and explanatory models. We have yet to study the impact of those efforts. Finally, our currently tentative findings obviously need disseminating among programme faculty if they are validated in subsequent development efforts.

Appendix

Prompt for 'reactive power' threshold concept:
Problem solver: Explain why a shunt inductor is normally used for reactive power compensation in a 400 kV transmission system, but a shunt capacitor is used in a 130 kV transmission system instead.

Listener could ask questions:

1. Does shunt inductor generate or consume reactive power? How about shunt capacitor? Why?
2. How does the loading of a transmission line affect the voltage, and thus the need of reactive power compensation? Under which loading and voltage conditions do we need inductive or capacitive reactive power compensation?
3. Does a 400 kV transmission line usually consume or generate reactive power? Why? How about 130 kV line?

Prompt for 'work curves' threshold concept:
Problem solver: Explain the work curves of concrete and steel and explain how these are mapped on to a cracked section of simple reinforced concrete loaded in bending. Draw the strain and stress distribution, and describe the corresponding internal force couple that react to the bending moment.

Listener could ask questions:

1. If a normal force in compression together with the moment acts on the section, how does the strain and stress distribution change?
2. What if the section is only steel, how does the strain and stress distribution change?
3. If the section is made of only concrete, how does the stress distribution change?

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