Language and Engineering: Towards Bilingual Scientific Literacy

John Airey
Högskolan i Kalmar
john.airey@hik.se

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Abstract

Two languages are usually used in the education of engineers in Sweden—the local language and English. There are clearly many benefits of this approach, but a number of interesting questions do arise. One such question relates to scientific literacy. If we accept that the overarching goal for engineering degree programmes is the production of scientifically literate graduates, then what is the nature of this scientific literacy when a programme involves two languages? Here, Airey and Linder have introduced a new construct: ***bilingual scientific literacy*** in order to characterise the particular set of language-specific engineering skills acquired by students.

This paper reports ongoing research results from the first Swedish study to be carried out into the relationship between the teaching language and disciplinary learning at university level. The study explored the teaching language (English, Swedish or both) and the related learning experiences of students from two Swedish universities. Students attended physics lectures in both English and Swedish as part of their regular undergraduate programmes. These lectures were videotaped and students were then interviewed about their learning experiences using selected excerpts of the video in a process of stimulated recall.

The work reported here concerns evaluation of a number of techniques that may be used to estimate bilingual scientific literacy. Student ability to use both English and Swedish to spontaneously describe and explain the concepts met in their lectures is analysed in terms of; linguistic fluency, code-switching, and 'disciplinary fluency'(as determined by science teachers). This is cross-referenced with the language in which the original material was taught (Swedish, English, or both languages). The implications of the findings thus far are discussed.

Introduction

Here in Sweden engineering undergraduates meet two languages in their education: English and Swedish. The most common division between these languages is to have lectures in Swedish with course texts in English. However, the presence of a single exchange student on a course can change the lecture language to English (Airey, 2004). Moreover, with the implementation of the *Bologna declaration* on harmonisation of European education, the role played by English in Swedish higher education seems set to increase dramatically. This prompted the former vice-chancellor of Sweden's Royal Institute of Technology (KTH) to suggest that all higher education will be delivered in English within 10-15 years (Flodström, 2006).

Although the shift to teaching in English has often been welcomed by teachers and students, the research community is only beginning to understand the dynamics of these changes within the learning environment. One of the reasons for this is that there is very little research available into the effects on disciplinary learning in higher education when the language used to teach a course is changed in this way. For example, both Met and Lorenz (1997) and Duff (1997) have suggested that limitations in a second language may inhibit students' ability to explore abstract concepts in their area of study. However, even without the added complication of a second language, the language aspect of disciplinary learning is particularly problematic and complex.

Östman (1998) points out that a disciplinary language is abstract and represents special communicative traditions and assumptions. On a similar theme, Säljö (2000) has argued that difficulties in student learning are in fact difficulties in handling and understanding highly specialised forms of communication which are not found to any great extent in everyday situations. Lemke (1990) has thus concluded that learning a subject such as engineering depends on the ability to understand the disciplinary language in which the knowledge is construed. With so many writers pointing out the complex, non-trivial nature of the relationship between language and disciplinary learning, one might expect to find an extensive body of research into the subject—particularly when it comes to *changing* the disciplinary language to English. Unfortunately, there is very little research that can inform the current language shift occurring in higher education.

Internationally there are only a small number of studies that have examined the effects of the teaching language on disciplinary learning in higher education. These international studies point to negative correlations between disciplinary learning and changing the teaching language to English (Gerber, Engelbrecht, Harding, & Rogan, 2005; Klaassen, 2001; Neville-Barton & Barton, 2005; Vinke, 1995). However, in the most comprehensive of these studies Klaassen (2001) found that the negative effects on disciplinary learning disappeared over the period of a year. Klaassen concluded that the students in her study had adapted to the language switch, and suggested follow-up work to identify the mechanisms by which this adaptation may occur.

Until recently no Nordic research had been carried out into the relationship between the teaching language and disciplinary learning at tertiary level. This situation changed with the publication of the results of a Swedish study which examined the disciplinary learning of undergraduate physics students who were taught in both Swedish and English (Airey, 2006a, 2006b; Airey & Linder, 2006; 2007). Building on Klaassen's earlier experiences in the Netherlands, this study showed that, whilst on the whole students believed that the teaching language had little effect on their learning, the same students could witness to a number of significant differences in their learning when commenting on video footage of teaching situations. The differences found involved the amount of interaction in lectures (students asked and answered fewer questions when taught in English) and a greater focus on the process of note-taking in English-medium teaching at the expense of following the lecturer's line of reasoning. Importantly, the students in the study changed their learning strategies to adapt to the language shift in a number of ways: some students read sections of work before lectures, whilst others no longer took notes in class. However, in some cases lectures had simply become sessions for mechanical note taking with extra work needed to make sense of these notes later.

The research detailed above is very useful information for teachers who need to teach their students in English, but it leaves the question of *when* we should be using English unanswered. Unfortunately, as pointed out in the introduction to this paper, this decision to change the teaching language to English often has little to do with achieving specific disciplinary learning objectives. This paper reports a first attempt to document the outcomes of using English in the education of Swedish engineers taking as its starting point the production of *scientifically literate graduates*.

The goal of engineering education: scientific literacy

Why do our students spend four years learning undergraduate engineering? One answer to this question is that we want to produce *scientifically literate graduates*. The term science literacy was first coined by Hurd (1958), but since then there has been little agreement as to its precise meaning (Laugksch, 2000). Usually when we talk about literacy we mean being able to read and write. In this respect, Norris and Phillips (2003) have suggested that literacy takes two forms; *fundamental* and *derived*. Fundamental literacy is the ability to extract meaning from text, whilst derived literacy refers to the use of knowledge in a particular context. Clearly, then, from this point of view, the fundamental form of *scientific* literacy involves being able to extract appropriate meaning from a science text (and other representations such as mathematics, graphs, tables, etc.) but when one comes to derived scientific literacy there are questions of context that need to be answered. Here, Roberts (2007) has aided our thinking by introducing the notion of two *visions* of scientific literacy: Vision I—coming to understand the content of science itself, and Vision II—coming to understand the implications and applications of science, particularly in relation to everyday situations. He suggests that when we think about derived scientific literacy we are in fact referring to a combination of Vision I and Vision II. Thus, Roberts argues that the type of derived scientific literacy fostered by any given undergraduate engineering course will place itself somewhere on the continuum between these two complementary visions. Following this division, scientific literacy is now defined for the purposes of this article as both the ability to *work within science* and the ability to *apply science* to everyday life.

Bilingual scientific literacy

If we accept that the goal of engineering degree courses is the production of scientifically literate graduates, in line with the definition above, then what is the nature of this scientific literacy with respect to language? Here Airey and Linder (2008a; 2008b) have introduced a new term, *bilingual scientific literacy,* which they define simply as scientific literacy in two languages. They use this notion to characterise the particular collection of language-specific science skills fostered within a given degree course with respect to Roberts' two visions. Since reading is a receptive skill, whilst writing is a productive skill, they argue that bilingual scientific literacy should similarly be divided into receptive and productive components see figure 1.

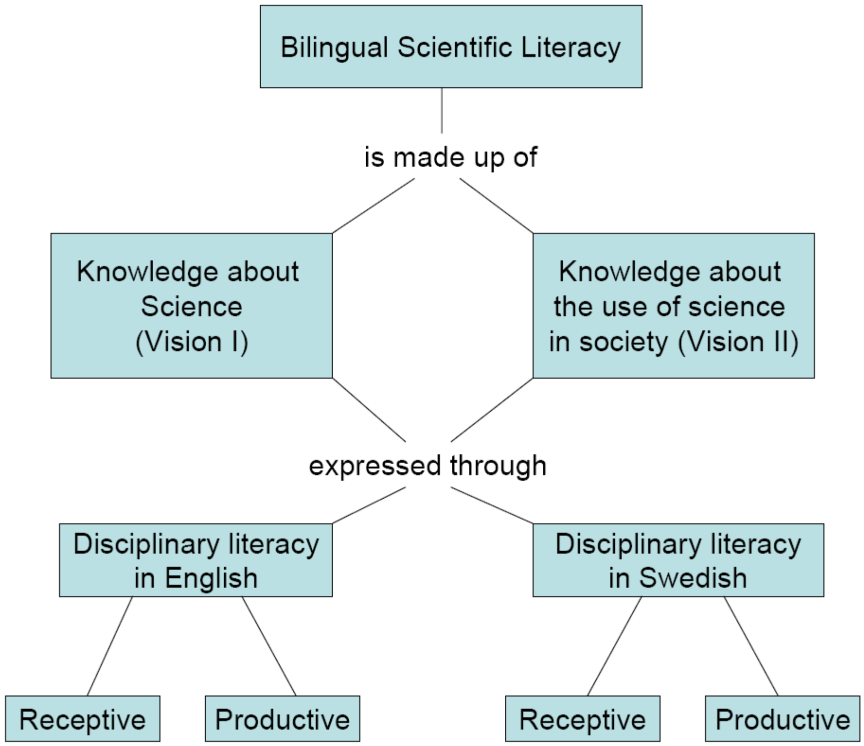


Figure 1
Bilingual scientific literacy in an engineering degree course syllabus.
Adapted from Airey and Linder (2008b)

Noting that no Swedish engineering degree syllabuses specify educational outcomes for all these components of bilingual scientific literacy in an explicit manner, Airey and Linder (2008b) attempted to access the *implied* goals of engineering degree courses. They report two main findings of their small-scale study. First, they suggest that courses appear to value literacy within the discipline (Vision I) over literacy with respect to the problems of everyday life (Vision II). Here they conclude that either lecturers do not see it as their job to encourage societal scientific literacy, or they assume that disciplinary literacy automatically leads to an ability to use science in an everyday context. The other main finding of the study is that there appears to be much more emphasis on receptive rather than productive components of bilingual scientific literacy—with the least practice being registered for spoken forms of scientific literacy in both Swedish and English. Airey and Linder thus identify a need for further research into the *actual* (rather than implied) levels of spoken bilingual scientific literacy achieved by students who follow Swedish engineering courses. As a continuation of the research documented above, this paper presents the first results of an ongoing study of students' spoken bilingual scientific literacy.

Assessing levels of bilingual scientific literacy

The main question that presents itself when contemplating the assessment of spoken bilingual scientific literacy is one of validity. What constitutes a legitimate measure of a student's ability to speak about science? In the field of linguistics there are a number of methods for assessing levels of speaking ability that can be used here. The majority of these linguistic measures assume a connection between speaking ability and speech rate—this is because higher speech rate is seen as an indicator that knowledge has become proceduralised (Anderson, 1982). The most basic method used in linguistic studies is *words per minute* (WPM)—this method has the benefit of being easily recognisable to most readers as a well-established measure of typing speed. However, Hincks (2005:114) points out that when comparing speech rate *between* languages it may be more appropriate to use *syllables per second* (SPS) rather than WPM. This is because average word length can vary significantly between languages. Finally, a number of studies have claimed that the most statistically significant measure of speaking ability is in fact the amount of speech uttered between pauses (Kormos & Dénes, 2004; Towell, Hawkins, & Bazergui, 1996). Here the average phrase length in syllables is calculated. In the literature this value is termed mean length of runs (MLR). Incidentally, MLR is also better suited to interview situations like the ones described in this paper since it eliminates the need to isolate and calculate the total speaking time for a given individual.

Working at the Swedish Royal Institute of Technology (KTH), Hincks (2005; 2008) compared presentations on the same topic given by the same students in English and Swedish using the SPS and MLR measures. The main finding is that when her Swedish students speak English they pause more often, use shorter phrase lengths and speak on average 23% slower. However, Hincks advises caution when comparing speaking ability between students based on SPS and MLR, pointing out that there is a strong effect of individual speaking style which carries over to second-language speaking from a student's first language. Students who speak slowly with frequent pauses in their first language show a similar pattern in their second-language speech. Thus, any attempt to compare scientific literacy between students using MLR or SPS methods will need to account for individual differences in speaking patterns in some way. In her survey of earlier linguistic studies, Hincks (2008:22) finds that in the majority of studies the length of time used to designate a pause varies "between 200 and 300 milliseconds". The analysis presented in this paper takes a different approach, using a qualitative rather than quantitative assessment of pauses. Hence, in this study, only those pauses that are experienced as such by a listener are recorded. Whilst this method obviously makes comparison with earlier work problematic, I would argue that it gives us a more accurate measure of scientific literacy—trading as it does reliability for validity. The method also goes some way to taking into account the problem of variation in student speech patterns noted by Hincks.

Chambers (1997) discusses the types of pauses that exist in speech dividing them into natural and unnatural pauses:

> Natural pauses, allowing breathing space, usually occur at some clause junctures or after groups of words forming a semantic unit. Pauses appearing at places other than these are judged as hesitations, revealing either lexical or morphological uncertainty. These hesitations may be either simply a silent gap or marked by non-lexical fillers ("uh","um"), sound stretches (or drawls on words) or lexical fillers with no semantic information (such as "you know", "I mean"). (Chambers, 1997:539)

We can thus expect the difference between first and second-language speech to be in the frequency of unnatural pauses, indicating lexical gaps in the second language. However, these lexical gaps may be filled in a number of ways other than those mentioned by Chambers. A common method for filling a lexical gap is *circumlocution*, where the subject describes the missing lexical item in a number of other words. This type of substitution is of course impossible to detect when using software to count the number of pauses in a soundfile, but could nevertheless be argued to be a valid indicator of scientific literacy. Also, where two languages are involved, and speaker and listener share access to both languages, *codeswitching* (i.e. inserting a word or phrase from another language) may be employed as a useful alternative to circumlocution. The benefits of codeswitching in the learning environment have been widely documented, with researchers from a wide variety of backgrounds acknowledging that the use of two languages offers better opportunities for representing and accessing knowledge (See for example Fakudze & Rollnick, 2008; Liebscher & Dailey-O'Caine, 2005; Moreno, Federmeier, & Kutas, 2002; Webb, 2007; Üstünel & Seedhouse, 2005). Clearly, these positive effects of codeswitching only occur when both speaker and listener can understand the languages used. It is argued here that when estimating scientific literacy we should not assume this relationship between speaker and listener. Hence, for the purposes of the analysis used in this paper, a new term, *involuntary codeswitching* is introduced to describe a situation where codeswitching occurs in a monolingual setting. In the interviews conducted for this paper students were instructed to use one language exclusively for a given description. Any codeswitching that occured was thus deemed involuntary and indicative of a lexical gap in the language being spoken.

Finally, scientific literacy is about much more than production of proceduralised speech—the most important part of scientific literacy actually depends on *what* is said. In order to be deemed scientifically literate, what is said needs to make sense from a disciplinary perspective—in this case it must exhibit an understanding of engineering. Similarly, speech must also be relevant to the task at hand—a student's fluent meta-description of their own lack of understanding, although rating highly on the linguistic measures described above, may not give us much information about their scientific literacy. To summarise then, a viable estimation of bilingual scientific literacy could perhaps be made from some combination of the following variables: SPS or MLR, involuntary codeswitching and a judgement about the disciplinarity of what has been said. The remainder of this paper will attempt to evaluate the application of this set of approaches to estimating bilingual scientific literacy using actual student interviews.

Assessing bilingual scientific literacy through interviews

In this section, illustrative examples of student interview data from three types of teaching situation are presented: courses taught in Swedish, courses taught in English, and a course taught in both languages. Two examples are given for each of the three situations. After watching short video clips of a lecture they had attended, students were asked to describe and explain in both English and Swedish some of the concepts dealt with in the lecture.

The raw transcripts were prepared for analysis in four stages. First, all speech by the interviewer was deleted and marked by a double return in the transcript. Next, all noticeable pauses—both filled and unfilled—were marked by entering a single return. (this created a transcript of phrases of various lengths, each on its own line). Then, all utterances in filled pauses—where the student uses sounds such as aah, um, er, etc.—were deleted. Finally, each word in the transcript was divided up into syllables. The SPS value was calculated by dividing the total number of syllables in the transcript by the total student speaking time (interviewer speaking time was first subtracted from the total time). MLR was calculated by dividing the total number of syllables in the transcript by the number of text lines (excluding empty lines). Instances of codeswitching were highlighted in bold and a subjective judgement about the disciplinarity of the description was made, using the following criteria:

Grade	Label	Description
0.	**Unclassified**:	No inferences about student scientific literacy can be made from the sequence (none presented in this data set).
1.	**Weak**:	Student clearly has major problems when talking about disciplinary concepts in this language.
2.	**Intermediate**:	Student uses some disciplinary terms appropriately, but either has clear disciplinary lexical gaps or uses some terms inappropriately.
3.	**Good**:	Student uses disciplinary terms appropriately in the sequence, but does not develop ideas fully.
4.	**Excellent**:	Expert explanation.

Courses taught in Swedish

The following two pairs of transcripts are from students talking about concepts presented in lectures in Swedish.

Student A:

This course dealt with the different types of mathematical series that can be useful for solving engineering problems.

Swedish description

1 Nej allt så,
2 lik form er at kon ver gens var in te in tu i tivt
3 klart,
4 var för man in te kan väl ja,
5 då väl jer ett om det finns
6 ett n för al la x var för kan man in te ta den stör sta först lik som?

SPS 3.7 MLR 8.7 Disciplinarity 3

English description

1 Yeah, I think so, yeah

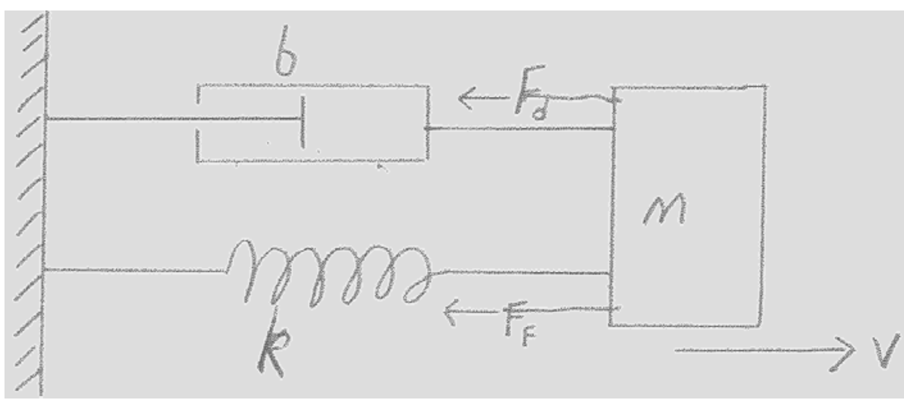
2 all the part ab out this su pre mum well, that was clear to me.
3 this last
4 part a bout un i form con ver gence it's
5 well, it's not **in**
6 **in tu it**
7 **in tu i tiv.**

SPS 1.95 MLR 6.1 Disciplinarity 3

This first student shows the anticipated pattern of reduced SPS and MLR values when talking about concepts in English that has been found in previous studies. There is one lexical gap in the English description, although the word ‘intuitive’ that the student is searching for has no real bearing on scientific literacy. Although the student gives a reasonable account in both languages these two descriptions do highlight a number of problems for this study of bilingual scientific literacy. First, from a methodological point viewpoint, it can be difficult to find longer stretches of speech that can be analysed from this sort of interview setting. This increases the uncertainty in the SPS and MLR values. Second, since students are learning the concepts through the lecture, their descriptions are of their *learning of the concept*, rather than of the concept *per se*. This makes the estimation of disciplinarity more complex than initially anticipated.

Student B: course taught in Swedish

In this course students were introduced to the damped harmonic oscillator. The lecturer drew following diagram on the whiteboard and discussed the consequences of adding the damping cylinder to the simple mass and spring system.



Swedish description

1 jo, allt så
2 jo, jag tror det allt så om man tar
3 o kej
4 jag tän ker in te så myc ket på b gån ger v allt så b gån ger has tig het en den är kon stant ”b gån ger v vad är det ta e gent lig en?”, u tan
5 a ha, han säg er
6 det allt så

7 den sam man lag da kraf ten är fjä derns kraft mi nus
8 kraf ten från den här dämp nings sys tem et
9 som är lik a med den sam man lag da kraft som är lik a med mass an gån ger ac cel er a tion en
10 det för står jag men jag tän ker in te så myc ket på
11 var i från kom mer vad är det här b gån ger
12 gån ger has tig het en u tan

SPS 4.1 MLR 12 Disciplinarity 3

English description

1 o kay
2 this
3 the mass which is
4 **ska jag pra ta på**

5 **mass an**
6 the mass which is
7 **det är svårt allt så**
8 which is
9 **fast?**

10 con nec ted to, to a
11 spring
12 and on here we have
13 **dämp nings sys tem** which al so is con nec ted to the mass.

14 this is the ve lo cit y
15 of the mass
16 this is the **fjä fjä der kraft en som ver kar i mot satt rikt ning**
17 **som**
18 which
19 acts in the op pos ite side
20 to the dis place ment
21 this is
22 the spring con stant
23 which de ter
24 mines the spring
25 and this is
26 **dämp dämp nings kon stant** which det erms the
27 **dämp nings sys tem**

SPS 2.0* MLR 4.4* Disciplinarity 1-2
*Note: actual values are in fact much lower due to the high amount of Swedish in the transcript.

Clearly, this student has extreme difficulty talking about science in English—so much so that the SPS and MLR values from the English transcript become effectively unusable due to the high proportion of Swedish. Interestingly, the student had few problems using English to talk about her background and the organisation of the course, giving reasonably fluent descriptions of these in the introductory part of the interview. We can thus conclude that it is precisely scientific literacy in English which is absent. One methodological point to note is that the student appears to use the word ‘alltså’ as a filler (see lines 1, 2, 4, and 6). In this respect a case could be made to delete the word, adding a pause to the transcript. However, in the interests of comparability, it was decided to only delete utterances that are experienced by the listener as a pause or hesitation. This is because in other situations the decision about what to classify as a filler is by no means so clean-cut.

Courses taught in English

The following two pairs of transcripts are from the *same two students* but now talking about concepts presented in lectures they attended in English.

Student A

This course in electromagnetism in English was read in parallel with the mathematics course in Swedish described earlier. The lecture discussed in the interview dealt with the derivation of Maxwell’s equations. The particular interview section chosen dealt with the following modification.

$$\boxed{\nabla \times \mathbf{E} = 0}$$

$$\downarrow$$

$$\boxed{\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}.}$$

Swedish description

1 ja, ja den be ty der ju,
2 att
3 the **curl** of E då är
4 är mi nus de ri va torn av B fält et men
5 sen just vad en **curl** är det har man fort far an de in te rik tigt fått en så här
6 di rekt in, in tu it ivt, bild av det

SPS 2.6 MLR 9.5 Disciplinarity 3

English description

1 Yeah,
2 well what he says right now is
3 ba sic lly is that the E field is a con ser va tive field
4 even though a ma the ma ti cian would n't say that
5 but
6 which al lows us to
7 to cre ate a po ten tial and
8 al so it says that
9 a line in te gral
10 de scri bing the work for ex am ple is

in de pen dent of, in de pen dent of time
in this, when you've got the ze ro there

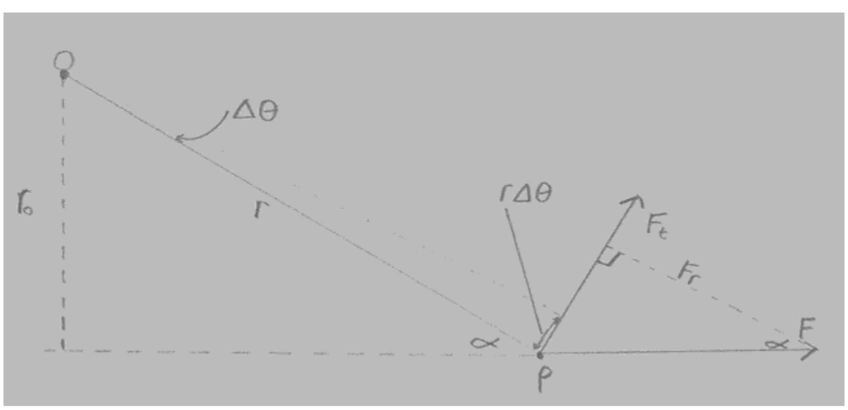
SPS 2.3 MLR 7.4 Disciplinarity 3-4

Interestingly this student, though taught in English, has no major problems in describing the content in Swedish—the student exhibits a high level of bilingual scientific literacy. However the best disciplinary description is given in the language in which this course was taught—English. We can also see another thought-provoking aspect of bilingual scientific literacy. This student codeswitches in his first language—Swedish—using the word ‘curl’ (lines 3 and 5) instead of the more usual ‘rotation’. We can of course argue that this term is fairly standard—indeed, it would be unthinkable for another Swedish engineer to misunderstand this description—but it does serve to highlight a potential risk. When teaching in English it may difficult to assess whether our students have acquired appropriate Swedish disciplinary terminology.

Student B

This course in rotational mechanics in English was read in parallel with the oscillations course in Swedish described earlier. The lecture discussed in the interview dealt with the analogy between straight line and rotational mechanics. The lecturer drew the following on the whiteboard during the course of the lecture.

One-dimensional motion	Two-dimensional motion
x position of the particle	Angle θ how far the body has rotated
Velocity $v = dx/dt$	Angular velocity $\omega = d\theta/dt$
Acceleration $a = dv/dt = d^2x/dt^2$	Angular acceleration $d\omega/dt = d^2\theta/dt^2$
Force	Torque $\tau = xF_y - yF_x$
Momentum	Angular momentum $L = xP_y - yP_x$



$$\Delta w = F_t \, r\Delta\theta = \tau\Delta\theta$$

$\tau = F_t r$ ①

$F_t = F\sin\alpha$

$\tau = F\sin\alpha r$

$\tau = Fr_o$ ②

Swedish description

1 nej jag tyck te e gent lig en det här var gan ska
2 o kej den här är lit e kon stig [points to torque expression in the table]
3 den här **torque** gre jen
4 den är lit e kon stig och den ock så [points to angular momentum expression in the table]
5 men ann ars att
6 **tor quen** är an a lo gen till kraf ten i en di men sion
7 det för står jag
8 och ac cel er a tion en

9 ja.
10 allt så in te så my cket.
11 jag har in te tänkt så my cket om dem, allt så jag
12 jag har nog kört på att jag tar det som det är
13 jag har in te för sökt re da ut det
14 u tan det det ac cep te rar jag ba ra att o kej så här räk nar man ut den
15 så här får man ut den
16 och så här får man ut den
17 den för står jag in te rik tigt

18 vrid kraft en
19 som sva rar mot en kraft i en di men sion

SPS 3.7 MLR 8.7 Disciplinarity 2

English description

1 this e qua tion [equation ①]
2 **jag allt så ja**
3 the
4 the torque
5 **allt så**
6 **jag kan lä sa ut vad det vad det**

7 o kay the torque
8 **kraf**
9 the tan gen tia
10 the tan gen tial force times the dis tance
11 to the point P
12 from the
13 ax is

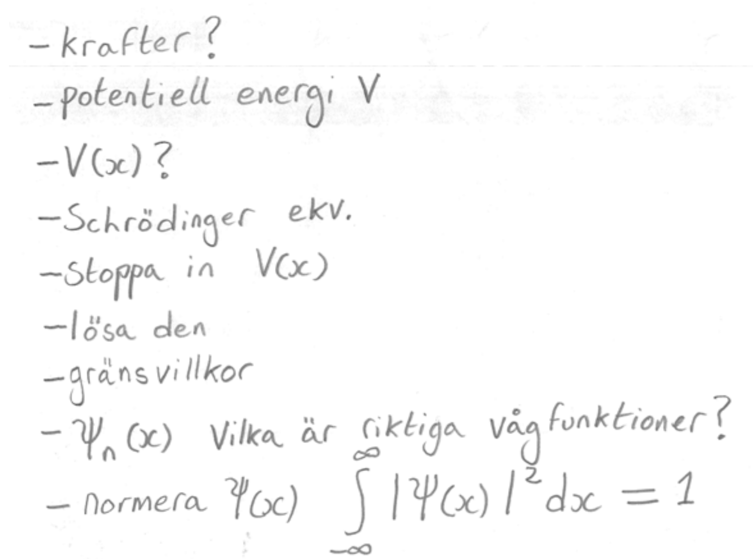
SPS 1.6 MLR 3.8 Disciplinarity 1-2

This student also codeswitches in Swedish (lines 3 and 6) but later finds the appropriate Swedish term (line 18). Once again we see that despite now discussing something taught in English, this student still has enormous problems with English scientific literacy. Although we cannot draw conclusions from such limited material, it is interesting to note that this interview took place in the early stages of the first course this student had read in English. In comparison, student A’s more fluent descriptions came well into that particular course, and after previous experience of reading courses in English. Taken together then, the interviews with these two students may give some anecdotal support for Klaassen’s (2001) finding that the negative effects of a language shift to English disappear after a period of a year.

Course taught in both languages

The following two pairs of transcripts are from students attending the same course in introductory quantum physics. The main lectures on this course were taught in English due to the presence of a number of exchange students in the group. However, when this large group was divided up for problem solving sessions one group was taught in Swedish. It is these students—effectively taught by the same lecturer in two languages—who form the basis of this dataset. The course was offered in the first year of study and thus represents the students’ first experience of being taught in English.

In the main session, the lecturer discussed in English the various conditions that the wavefunction must satisfy. Later the same day, the lecturer discussed a strategy for solving quantum mechanical problems in Swedish, writing the following on the whiteboard:



Student C

Swedish description

1 att
2 psaj
3 psee psee psaj
4 kan in te

5 kan in te va ra
6 vil ken funk tion som helst om man viss a
7 viss a viss a
8 be gräns nin gar för vad man kan
9 hur man kan lö sa den
10 den
11 di ffer en ti al a ek va tion en
12 psaj mås te va ra en kon tin u er lig funk tion
13 den får
14 allt så den för var je x- vär de ell er mot svar an de vad det är på den na ax eln
15 får det ba ra finn as ett y –vär de
16 och
17 den får in te va ra
18 går mot o änd lig het en ell er mi nus o änd lig het en nå gon stans
19 och
20 och sum man av
21 av allt så a re an un der
22 un der gra fen
23 från plu mi nus o änd lig het en till plus o änd lig het en i x- led mås te va ra ett
24 allt så in te gra len
25 när man lö sa in te gra tion till plus o änd lig het en

SPS 3.0 MLR 7.5 Disciplinarity 3

English description

1 first if I
2 if I was gon na solve a prob lem a ccor ding to this plan
3 I was gon na
4 I would
5 I would
6 draw a pic ture of
7 the e lec tron or what it is
8 and
9 vis u lize
10 what what for ces that af fect the
11 the e lec trons and
12 what its po ten tial en er gy would be like
13 and then
14 there fore
15 and there af ter make some sort of a func tion of the po ten tial en er gy
16 de pen ding on the where
17 where the e lec tron
18 is
19 then
20 be cause you can
21 use that func tion in the schrö din ger e qua tion
22 to
23 solve
24 what
25 what
26 psaj would be like
27 psaj would be
28 what boun dry con di tions there are
29 I I’m not sure I don’t know
30 but that prob ab ly might be giv en in

31 in the
32 in the prob lem and I’m not sure how to use that

SPS 2.4 MLR 5.3 Disciplinarity 3

This student does a good job of describing the content of the lectures in both languages—this is in stark contrast to the other first year student in the study (student A) who was taught separate courses in English and Swedish and found it impossible to describe disciplinary concepts in English.

Student D

Swedish description

1 först så ska den va ra
2 **con tin u ous** den ska va ra kon tin u er lig den ska ha ett be stämt vär de längst he la
3 längst he la
4 kur van
5 ska inte finn as nå ra
6 dip par upp ell er ner
7 ell er vär den som in te ex is ter ar
8 in te säg noll eller nå gon ting
9 sen ska den va ra
10 den ska va ra änd lig
11 det ska var a en bör jan och ett slut
12 så
13 vad var det mer
14 och
15 vi tar den först
16 in te gra len av
17 den här
18 **prob a bil ity**
19 av sann o lik het en ska va ra ett
20 to tal sann o lik het en
21 någ on stans inom det
22 om råd et x mås te e lek tron en fin nas
23 och då så ska det va ra en funk tion var je vär de får
24 var je
25 x- vär de får ba ra ha ett y- vär de

SPS 2.6 MLR 6.6 Disciplinarity 3

English description

1 identify the forces on the
2 the par ti cle
3 on the
4 the mov ing par ti cle
5 that’s quite straight for ward
6 it’s the
7 it’s the cen tri pet al force and the force in wards
8 be cause of the
9 force of a ttrac tion be tween the
10 the par tic les
11 I would I mag ine

12 I have n’t real ly looked at this yet so I
13 I’m not sure
14 and the
15 the po ten tial en er gy
16 how
17 how it
18 how it looks
19 the
20 the func tion
21 and how it chang es with
22 var y ing
23 dis tance
24 that I can un der stand as well
25 its quite
26 quite straight for ward
27 how to
28 de rive a
29 an e qua e qua tion func tion v of x to put in to Schrö ding ers equation
30 that
31 that can be more di ffi cult
32 task
33 I think
34 and
35 I don’t know what she means by solving schrö ding ers e qua tion be cause
36 you still have the psaj
37 of x

SPS 1.9 MLR 4.9 Disciplinarity 2-3

As with student C, student D manages to give a reasonable description in Swedish. Although the student codeswitches twice, the lexical gaps are directly followed by the appropriate Swedish term. There is some question about the disciplinarity of the English description, with the student seeming to relate the potential energy v(x) to orbiting electrons rather than the particle in a box description that had been used in the lecture.

Discussion of techniques used to assess bilingual scientific literacy

We are now in a position to evaluate the contributions of the various measures to an understanding of student scientific literacy:

- **SPS and MLR**
  The SPS and MLR values appear to provide similar information about the fluency with which speech is produced. It could perhaps be argued that MLR gives a more accurate and comparable reflection of scientific literacy, since only pauses that are experienced by a listener as such are recorded in this study. More data is required before any judgement about the appropriacy of these two measures can be made.

- **Involuntary codeswitching**
  The introduction of involuntary codeswitching appears to be a useful indicator of students’ scientific literacy. Surprisingly perhaps, disciplinary lexical gaps were also documented in the Swedish transcripts.

- **Disciplinarity**
  The estimation of disciplinarity, though somewhat difficult to assign, does serve to distinguish between students who have weak scientific literacy and those who have fair-good-excellent SL. This is an important point since this is something that is not reflected in the purely linguistic SPS and MLR values.

Tentative conclusions and future work

The analysis of the limited dataset presented in this paper is a first attempt to estimate students' oral bilingual scientific literacy from interviews, and to relate this estimation to the teaching language used. As such the paper should be read as a discussion of the methods needed for such work and clearly cannot claim to make recommendations as to the organisation of undergraduate engineering programmes. However a number of issues have been raised which need further investigation:

The problem of English scientific literacy

It is clear from the data that some students do have problems describing science concepts in English. Data from elsewhere suggests that this may be something that reduces over time. Whether this is indeed the case, and if so, whether this reduction in problems is simply due to student drop-out or the adaptation strategies mentioned earlier in this paper is a major question for Swedish engineering education. The continuing analysis of the data collected in this study may help shed some light on this important area.

Teaching in two languages

In this study three of the students were experiencing teaching in English for the first time. It is noticeable that the two students who were taught using a dual-language approach performed better than the student who was taught exclusively in English. This may, of course, be pure coincidence and further work is needed to assess whether a dual-language approach is indeed a useful method for introducing students to teaching through the medium of English.

Teaching in English

The one student in this study who had previous experience of courses in English exhibited high levels of English scientific literacy without any apparent negative effects on his Swedish scientific literacy. Whether this is common pattern and if so why this should be the case is an area that I intend to investigate in my future research.

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References

Airey, J. (2004). Can you teach it in English? Aspects of the language choice debate in Swedish higher education. In R. Wilkinson (Ed.), *Integrating Content and*

Language: Meeting the Challenge of a Multilingual Higher Education (pp. 97-108). Maastricht, Netherlands: Maastricht University Press.

Airey, J. (2006a). När undervisningsspråket blir engelska [When the teaching language is changed to English]. *Språkvård, 2006*(4), 20-25.

Airey, J. (2006b). *Physics Students' Experiences of the Disciplinary Discourse Encountered in Lectures in English and Swedish*. Licentiate Thesis. Uppsala, Sweden: Department of Physics, Uppsala University.

Airey, J., & Linder, C. (2006). Language and the experience of learning university physics in Sweden. *European Journal of Physics, 27*(3), 553-560.

Airey, J., & Linder, C. (2007). Disciplinary learning in a second language: A case study from university physics. In R. Wilkinson & V. Zegers (Eds.), *Researching Content and Language Integration in Higher Education* (pp. 161-171). Maastricht: Maastricht University Language Centre.

Airey, J., & Linder, C. (2008a). Bilingual Scientific Literacy. *Paper presented at the 2008 Canadian Society for the Study of Education Conference*, University of British Columbia, Vancouver, Canada.

Airey, J., & Linder, C. (2008b). Bilingual scientific literacy? The use of English in Swedish university science programmes. *Nordic Journal of English Studies, 7*(2).

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review, 89*(4), 369-406.

Chambers, F. (1997). What do we mean by fluency? *System, 25*(4), 535-544.

Duff, P. A. (1997). Immersion in Hungary: an ELF experiment. In R. K. Johnson & M. Swain (Eds.), *Immersion education: International perspectives* (pp. 19-43). Cambridge, UK: CUP.

Fakudze, C., & Rollnick, M. (2008). Language, Culture, Ontological Assumptions, Epistemological Beliefs, and Knowledge about Nature and Naturally Occurring Events: Southern African Perspective. *L1 – Educational Studies in Language and Literature, 8*(1), 69-94.

Flodström, A. (2006). *Allt fler universitet undervisar på engelska [More and more universities teach in English]*: Television debate in: Gomorron Sverige [Swedish Breakfast Television]. Broadcast: 06.43 to 06.55, 18 April, 2006.

Gerber, A., Engelbrecht, J., Harding, A., & Rogan, J. (2005). *The Influence of Second Language Teaching on Undergraduate Mathematics Performance*. Retrieved 23 September 2005, from http://ridcully.up.ac.za/muti/language.pdf

Hincks, R. (2005). Computer support for learners of spoken English. *Doctoral Thesis in Speech and Communication. Stockholm. Sweden*.

Hincks, R. (2008). *Presenting in English or Swedish: Differences in speaking rate.* Paper presented at the FONETIK 2008, Department of Linguistics, University of Gothenburg.

Hurd, P. d. H. (1958). Science literacy: Its meaning for American schools. *Educational Leadership, 16*, 13-16.

Klaassen, R. (2001). *The International University Curriculum: Challenges in English-Medium Engineering Education*. Delft: Department of Communication and Education, Delft University of Technology.

Kormos, J., & Dénes, M. (2004). Exploring measures and perceptions of fluency in the speech of second language learners. *System, 32*(145-164).

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84:*, 71–94.

Lemke, J. L. (1990). *Talking science: Language, learning and values.* Norwood, NJ: Ablex.

Liebscher, G., & Dailey-O'Caine, J. (2005). Learner Code-Switching in the Content-Based Foreign Language Classroom. *The Modern Language Journal, 89*(ii), 234-247.

Met, M., & Lorenz, E. B. (1997). Lessons from U.S. immersion programs: Two decades of experience. In R. K. Johnson & M. Swain (Eds.), *Immersion education: International perspectives* (pp. 243-264). Cambridge, UK: CUP.

Moreno, M., Federmeier, K., & Kutas, M. (2002). Switching Languages, Switching Palabras (Words): An Electrophysiological Study of Code Switching. *Brain and Language, 80*, 188–207.

Neville-Barton, P., & Barton, B. (2005). *The Relationship between English Language and Mathematics Learning for Non-native Speakers*. Retrieved 21 Sept. 2005, from http://www.tlri.org.nz/pdfs/13909.pdf

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*(2), 224-240.

Roberts, D. (2007). Scientific literacy/science literacy: Threats and opportunities. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729-780). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Säljö, R. (2000). *Lärande i praktiken: ett sociokulturellt perspektiv [Learning in practice: a sociocultural perspective]*. Stockholm: Prisma.

Towell, R., Hawkins, R., & Bazergui, N. (1996). The Development of Fluency in Advanced Learners of French. *Applied Linguistics, 17*(1), 84-119.

Vinke, A. A. (1995). *English as the Medium of Instruction in Dutch Engineering Education*. Delft: Department of Communication and Education, Delft University of Technology.

Webb, P. (Ed.). (2007). *Scientific literacy: A new synthesis* (3 ed.). Port Elizabeth, South Africa: Bay Books.

Üstünel, E., & Seedhouse, P. (2005). Why that, in that language, right now? Code-switching and pedagogical focus. *International Journal of Applied Linguistics, 15*(3), 302-325.

Östman, L. (1998). How companion meanings are expressed by science education discourse. In D. Roberts & L. Östman (Eds.), *Problems of meaning in science education* (pp. 54-70). New York: Teachers College Press.