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EST for EMI: A Problem-Based Learning Approach to Domain-Specific Fluency

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An English for Science and Technology (EST) course is offered as a potential bridge to English as a Medium of Instruction (EMI) in the sciences. Consisting of four modules, each organized around a "big problem" in science or technology, the course challenges students to collectively arrive at solutions through critical and creative thinking that ultimately finds expression in three modalities: verbal (e.g., expert panel discussions, debates) graphic (e.g., problem statements, action plans), and visual-spatial (e.g., graphs, models). It is suggested that Problem-Based Learning (PBL) approaches to language learning – especially ones propelled by critical thinking frameworks (e.g., SPRE) – not only ease the transition to science courses where English is the medium of instruction but promote the acquisition of general competencies thought vital to 21st century success.

Keywords: English for science and technology, problem-based learning, critical thinking

According to a recent British Council interim report (Dearden, 2014), English as a Medium of Instruction (EMI), by which so-called content subjects such as math and history are taught in English in settings where it is not the national or official language, is a burgeoning global phenomenon. On the strength of several findings, Dearden goes so far as to characterize the trend as an outright "shift from English being taught as a foreign language (EFL) to English being the medium of instruction (EMI) for academic subjects such as science, mathematics, geography and medicine" (Dearden, 2014, p. 2). This surge in EMI, in particular for STEM (i.e., science, technology, engineering, math) subjects (Langdon, McKittrick, Beede, Khan, & Doms, 2011), has recently been the focus of several professional language teaching forums and conferences (e.g., British Council Emerging Forum 4, 2014; ESP/EAP/EMI in the Context of Higher Education Internationalization, 2014) as EMI specialists grapple with the formidable challenges of their "dual pedagogical role": that of facilitating, at once, the acquisition of scientific content and foreign language (English) skills.

EMI and Internationalization

This author, a teacher of English for Science and Technology (EST) and EMI at the New Economic School (NES), counts herself among those coming to grips with the aforementioned "dual pedagogical role". In an ongoing effort to "internationalize", NES, a renowned institute of higher education in Moscow, has employed and hosted professors and lecturers from around the world. It has also vigorously engaged in the exchange of students, faculty, and ideas with affiliated foreign universities, laboratories, and think tanks and maintains a high profile at professional conferences and symposia both within and without Russia. From a cultural diversity standpoint surely this is an "embarrassment of riches", with a multitude of nationalities, languages, and worldviews all united in the mission of furthering knowledge within the spheres of economics, finance and related disciplines.

But despite its unique (to Russia) global outreach and wealth of international human capital, the existence of linguistic communicative barriers between NES students - the vast majority of whom are Russian nationals - and their foreign English speaking instructors cannot be denied. This is especially true of students of low and intermediate English proficiency, who, understandably, struggle to keep pace with “supersaturated” lectures in specialized subjects (e.g., microeconomics, econometrics, etc.) delivered entirely in English. What is more, the language barrier may be further aggravated by non-native English speaking instructors, who, owing to questionable proficiency, sometimes fall short in their quest to transfer complex knowledge to their learners. The problem is by no means unique to NES – is, in fact, a universal theme that cuts across all schools, primary through graduate, seeking to “internationalize” through EMI while striving to maintain the highest possible standards of academic instruction (see Deardon, 2014).

From the above it is clear that inadequate English proficiency on the part of the students, the teacher, or both can greatly diminish the likelihood of EMI course success. And if left to simply run their course, to work themselves out over time, student-teacher language gaps carry the potential of undermining the academic objectives of even the most innovative and globally-minded of institutions, however noble its mission.

Materials and Methods

EST for EMI: Bridging the Language Gap

In response to this observation an EST course has been developed, one specifically designed to mitigate the language gap that exists in EMI courses between non-native English speaking students and their teachers. The EST course, which could be offered prior to or run concurrently with EMI courses, is meant to ease the transition to EMI courses through the systematic implementation of a problem-based learning (PBL) approach (Barbara, Groh, & Allen, 2001; Barrows, 1996; Merrill, 2002; Schmidt, 1983) to language learning driven by a four-stage critical thinking framework (CTF).

Many English programs worldwide currently revolve around communicative (Nunan, 1991), thematic (Nunan, 1999), and learner-centered (Hutchinson & Waters, 1987; Nunan, 1988) approaches to language acquisition, with teachers encouraged to assume the role of language facilitator. Beyond this, however, is the growing realization among practitioners that language instruction is perhaps most effective when it calls upon students to perform meaningful tasks, solve real-world problems, or even contribute to their community via the target language. At the heart of task-, problem-, and community- based approaches lie critical thinking frameworks - from widely heralded Bloom’s Taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Krathwohl, Bloom, & Masia, 1964) and revisions thereof (Anderson, Lorin & Krathwohl , 2000) to lesser known vehicles such as SPRE (i.e., situation, problem, response, evaluation; adapted from standard “problem-solution texts”) and CIFA (i.e., contemplate, investigate, formulate, activate) (Hannigan, in progress), among others - that serve to not only structure but propel cognition. CTF-driven PBL cannot be emphasized enough, as it promotes not only domain-specific fluency but also the development of cognitive competencies (e.g., critical, independent, and creative thinking skills) en route to advanced proficiency. In dynamic approaches such as this, English is generally seen as a vital means to a worthy end rather than as the end, itself – a view that many second language learners, at least anecdotally, find both useful and satisfying. In what follows the design details of this particular EST course (hereafter referred to as the “EST prototype”), including its profile, integral components and module progression, are described in turn.

EST for EMI Course Design

Course Profile

The EST prototype herein presented is a domain-specific integrated skills course capable of addressing, with appropriate modifications, the language needs of students with CEFR (Common European Framework of Reference) proficiency levels of B1 through C2 (i.e., low intermediate through high advanced). Its overarching aim is to provide students with the academic and language skills they need for successful study or professional work in scientific contexts where English is the working language.

The EST prototype, taught by the author in the fall semester of 2014, was divided into four modules each consisting of three weeks (one week = two classes of 1.5 hours or more), with each module organized around a “big” problem in science or technology. Importantly, the course challenged students to collectively arrive at solutions to the module problems through critical and creative thinking that ultimately found expression in three distinct modalities, namely, verbal (e.g., expert panel discussions, presentations, etc.), graphic (action plans, research reports, etc.), and visual-spatial (graphs, models, etc.). The so-called “integral components” of the EST prototype are identified and explained below.

Results

Integral Components

Levels of analysis. The selection of "big" module problems for students to solve should first and foremost be guided by the "level of analysis" (LOA) at which the EST teacher - ideally in consultation with EMI instructors, language program administrators, and the students themselves (perhaps through a carefully executed "needs analysis) - decides to pitch the course. Below are descriptions of four different LOAs (see Table 1), collectively conceptualized as a nested structure ranging from "wide scope", where module problems are selected from separate domains of knowledge, or fields, to "fine scope", where all problems are drawn from a single subject area. It must be noted that, as with all nested structures, LOAs may extend infinitely in both directions – implying that the EST teacher is at complete liberty in setting even wider, or as the case may be finer, parameters if necessary. It is even possible to progress from one LOA to another within a single semester, for example, in the case where a learner goal might be to either generalize beyond or delve more deeply into a particular topic, point, or process.

By way of illustration, in the EST prototype students (Bachelor of Arts in Economics candidates) investigated with an eye to solving the following four potentially cataclysmic module problems: threat of asteroid impact, oceanic garbage mega-patches, loss of planetary biodiversity, and "problem X" (choice of the bid-winning team, which was bioterrorism) (see Figure 1 for a visual representation of these module problems). The choice of this particular LOA (LOA #2, see Table 1) was based on the perception that a balance of sorts ought to be struck between two prevailing student needs, namely, the need for English assistance in EMI economics courses (e.g., scientific discourse patterns, scientific structures, semi- or sub- technical vocabulary, etc.) (see West, 2013 for a description of semi- and sub- technical vocabulary relative to jargon) and the need to broaden students' knowledge base (i.e., "think outside the economics box"). The "happy compromise", here, was to select problems within the domain of science yet outside the fields of economics and finance – with the understanding that many discourse patterns, structures and vocabulary (at least at semi- and sub- technical levels) generalize across disciplines within the larger scientific domain. However effective with these undergraduates, LOA #2 might not be at all suitable for sciences graduate students, technicians, and professionals routinely immersed in highly specific subject matter. In these cases, LOA #3 or #4 (or an even finer scope) would perhaps be more appropriate.

Table 1
Module Problem Levels of Analysis

LOA #1: wide scope, or inter-domain Problems drawn from different "domains of knowledge", or fields: A science problem, a literature problem, a history problem, etc.
LOA #2: intermediate scope, or intra-domain Problems drawn from disciplines within a single "domain of knowledge": Domain = science: An engineering problem, a biology problem, a physics problem, etc.
LOA #3: narrow scope, or intra-disciplinary Problems drawn from subject areas within a single discipline: Discipline = engineering: An aerospace engineering problem, a biomedical engineering problem, a civil engineering problem, etc.
LOA #4: fine scope, or within-subject area Problems drawn from a single subject area: Subject area = civil engineering: A structural engineering problem, a transportation engineering problem, an environmental engineering problem, etc.

Once established, the LOA guides or even delimits the selection and creation of authentic EST course materials (e.g. academic/technical texts, [audio]visual segments, models, graphs, etc.), which, in turn, serve as the bases for the generation of custom-made projects, activities, and exercises targeted to specific needs.

SPRE critical thinking framework. Another integral component of the EST prototype was a four-stage CTF known as SPRE (see Table 2), a variant of the steps involved in crafting a standard "problem-solution text" (i.e., SPSE, or situation, problem, solution, evaluation). Over the years, SPRE has enjoyed widespread use in a variety of educational settings and contexts both within and without the field of language teaching.

Concerning the EST prototype, SPRE was ideal in that it required that each "big" problem be broken down into discreet stages for detailed analysis before being logically and creatively assembled, or synthesized, into a viable solution. Furthermore, as displayed in Table 2, each stage placed a unique cognitive demand on the students; that is, called on a different set of critical thinking and linguistic skills that culminated in verbal, graphic and visuospatial expression (see Table 3).

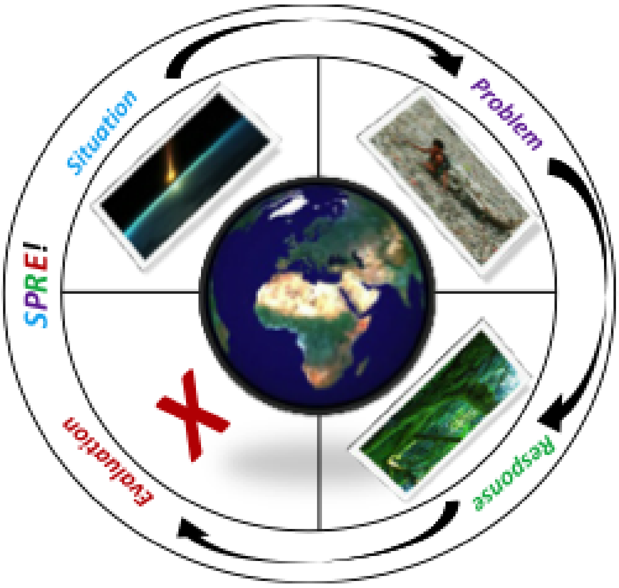

Figure 1. EST prototype module problems within the SPRE critical thinking framework.

In the EST prototype, which placed a high premium on cooperative learning, the class was divided into four "SPRE teams", with each team member assigned one of the four SPRE critical thinking stages. More specifically, again with reference to Tables 2 and 3, the "situation" member of a given SPRE team was tasked with preparing an "objective description" of the "big" problem (e.g., threat of asteroid impact) that was first orally presented in an "expert" panel discussion (refer to the section "Module Progression", below) and then formalized in a written report. Likewise, the "problem" member was tasked with devising a "problem statement" toward the panel discussion and written report, the "response" member an "action plan", and the "evaluation" member a "critique".

Table 2
SPRE Critical Thinking Framework

Situation Who? What? When? Where? Objectively describe or report dilemma.
Problem(s) What's wrong? What's the matter? Identify and prioritize the problems.
Response What specific steps must be taken and in what order? Generate an action plan.
Evaluation Will our response be effective? What are its pros and cons? Costs and benefits? What should be modified, added, eliminated going forward?

Noteworthy is the fact that the speaking and writing assignments for each SPRE stage correspond to, and therefore reinforce, those rhetorical modes of expression thought vital to scientific discourse. For instance, the "big" problem "objective description" corresponds to the rhetorical modes of description and classification, the "problem statement" to the mode of cause and effect, the "action plan" to the mode of process analysis, and the "critique" to the modes of comparison/contrast and argument.

Yet another virtue of the SPRE CTF is that it lends itself to dynamic, as opposed to static, problem-solving as students, both individually and collectively, must methodically work their way across problem stages to reach a conclusion. SPRE also actively promotes deep, or semantic-associative, processing (Craik & Lockhart, 1972): in order to formulate a worthy "action plan", for example, the "response" member must also have a handle on the "situation", the "problem", and the "evaluation" – a glorified jigsaw exercise of sorts demanding a high degree of communication and cooperation among teammates in the target language.

Discussion

Module Progression

Week 1: Introduce the module problem. As previously mentioned, the EST prototype was organized into four three-week modules, each exploring a different "big" problem in science or technology. The focus of the first week of each module was on introducing its problem through both an academic video/podcast (TED Talks, NPR, etc.) and a scientific journal article (JA). Comprehension

Table 3
Modalities of Expression: Threat of Asteroid Impact

Student 1: Situation Verbal, graphic and visuospatial "objective description" of asteroid impact.
Student 2: Problem(s) Verbal, graphic, & visuospatial "problem statement" of asteroid impact - based on Situation.
Student 3: Response Verbal, graphic, & visuospatial "action plan" in response to asteroid impact - based on Situation & Problem.
Student 4: Evaluation Verbal, graphic, & visuospatial "critique" of asteroid impact - based on Situation, Problem, & Response.

Table 4
SPRE Team Role Rotation across the EST Prototype Modules

	Module 1	Module 2	Module 3	Module 4
STUDENT 1	situation	problem	response	evaluation
STUDENT 2	problem	response	evaluation	situation
STUDENT 3	response	evaluation	situation	problem
STUDENT 4	evaluation	situation	problem	response

of the video/podcast was checked and reinforced with tailor-made listening comprehension and vocabulary exercises/activities designed to address specific learner needs. As for the JA, the primary foci were "busting" authentic scientific text (part 1) and heightening awareness of scientific discourse patterns through an assortment of reading comprehension and close reading (i.e., discourse analysis) exercises and activities.

Week 2: Solve the module problem. The major focus of Week Two was on solving the module problem introduced in the first week via the SPRE CTF. As mentioned above, the class was divided into SPRE teams each consisting of four students. Each team was then given a "problem scenario" (see Appendix A), which clearly specified the module problem and required that consensus be reached as to which member would be responsible for what SPRE stage – in all three modalities of expression (i.e., verbal, graphic and visuospatial). Team members then worked together (with the aid of SPRE "brainstorming squares") to devise verbal statements, one for each SPRE role, that were to be presented by each student in a series of "expert" panel discussions scheduled to occur in class the following week (see Appendix B) . The panel discussions were pivotal in that they served as both the primary speaking assessment and as a pre-writing activity for all written assignments.

Noteworthy is the fact that each and every student experienced all stages of the SPRE CTF through a carefully monitored SPRE role rotation system as shown in Table 4.

Another goal of the second week was JA "busting" (part 2), with special foci on grammatical structures common to scientific discourse, the interpretation and expression of scientific figures such as graphs, models and tables, and scientific source documentation.

Week 3: Express the solution to the module problem. The objective of the third week of each module was for students to synthesize and actualize the listening and reading comprehension, vocabulary, grammar, discourse analyses, and panel discussion preparation of the previous two weeks by (1) providing their "expert" opinion on the module problem via a panel discussion (speaking assessment), and then (2) beginning to set their verbalized – and therefore well-processed – thoughts to paper in an organized and coherent fashion (SPRE-based written assessment) with the assistance of "pre-writing" activities that included brainstorming, planning, and outlining via SPRE essay construction templates.

Capstone project. The EST prototype culminated in a "Causal Web Synthesis, "ultimate PBL" that challenged each SPRE team to creatively, yet convincingly, demonstrate how modules 1-4 are interrelated; that is to say, inextricably entwined, illustrating how precariously our planet hangs in the balance. Please refer to Appendix C for a full description of this capstone project.

Future Directions

The author would embrace the opportunity to teach a variant of the EST prototype in a different context, for a different purpose, and at a different LOA in an ongoing quest to prepare students for EMI sciences courses. In addition, she looks forward to piloting an intermediate level integrated skills course incorporating the principles and ethos of community-based learning.

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Appendix A

EST Prototype Problem Scenario

~ Module 1: Asteroid Impact ~
Speaking Assessment: Expert Panel Discussions!

IMMINENT THREAT: An asteroid approximately 1.02 kilometers in diameter is hurtling toward Earth at speed of 40 km per second. Ground-zero is estimated within 100 kilometers of the Siberian city of Novosibirsk, Russian Federation; estimated time of impact is 15 days - 2 hours - 31 seconds - 17 milliseconds and counting!

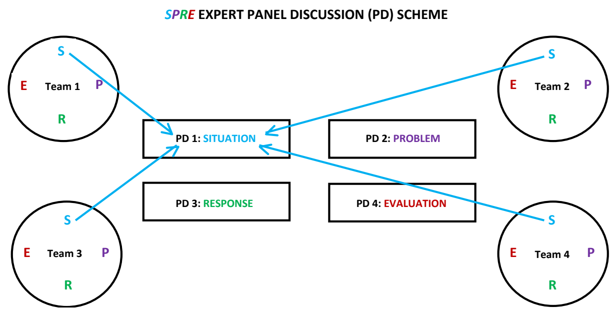
TASK 1: As a leading team of astrophysicists and aeronautical engineers at the IPPA (International Planetary Protection Agency), your job is to avert cataclysmic disaster by clearly and concisely articulating an ironclad solution consisting of 4 parts: Situation, Problem(s), Response, and Evaluation. You will present your solution as "experts" in a series of "asteroid panel discussions" scheduled to take place in class next week.

TASK 2: Reach consensus with teammates as to panel discussion roles by filling out the chart, below. I will collect one from each team by the end of class today.

EXPERT PANEL MEMBERS	PROBLEM-SOLVING ROLES
(1)	SITUATION
(2)	PROBLEM
(3)	RESPONSE
(4)	EVALUATION

Appendix B

Panel Discussion Scheme



Appendix C

Capstone Presentation Guidelines

~ Inextricably Entwined? ~

English for Science & Technology: Causal Web Synthesis (CWS)

In teams, work toward satisfying the ENG 371 course challenge of demonstrating how the four module problems (MPs) are causally linked by following the three CWS steps outlined below. Not mandatory, but you may find "Linked" book chapters (1st, 6th, & 9th Links) of conceptual and theoretical value, here. You are also encouraged to draw on other credible sources so long as they are properly cited (CMS documentation).

STEP 1: Depict it!

Think of a creative yet effective way to visually (other senses are of course welcome, too!) demonstrate how the four MPs are interconnected, that is to say, inextricably entwined. The visuospatial medium is entirely up to you. It could be physical, electronic, multisensory, multidimensional, static, dynamic, terrestrial, aquatic, cosmic - WHATEVER!

- Your depiction must be plausible, that is, defensible by way of clear example, sound reasoning, and credible evidence where possible.
- Your depiction must be captivating - conceptually intriguing and aesthetically pleasing.
- Your depiction must be presentable - fit into and function as intended within the limiting factor that is our classroom!

STEP 2: Describe it!

Verbally walk the audience through (i.e., describe) your depiction by:

- Providing a brief **rationale** for it. Why have you elected to represent MP interrelationships in this particular way and not in some other way?
- Introducing its **basic units**, if any. What are your depiction's building blocks? Boxes & arrows? Links & nodes? Weakly connected clusters? Hubs & Spokes? Waves and/or particles? Properties? Dimensions?
- Expressing the **process(s)** by which isolated events (e.g., the four MPs) conspire, perhaps irrevocably, to perturb "the whole" - to become "the whole". In your depiction, how are the MPs linked such that the demise of one leads to the demise of others, which in turn lead to the demise of still others (cascade or domino effect)? Constraints? Weights? Formulas? Rules? Laws? Critical thresholds (tipping points)? Distributions [random, bell-shaped, scale-free]?
- Concluding with your **prediction** for the future. Will earth experience a "total systems failure"? Will the science that got us into this mess evolve to the point where it can get us out of it? Can Homo sapiens muster the collective will to prevent self-annihilation?

STEP 3: Present it!

- Your depiction will be exhibited (Step 1) and described (Step 2) during "finals week". Exact date TBA.
- Each team will have 15-20 minutes to present their CWS. Time limit strictly enforced.
- An equitable division of labor among teammates must be in evidence for both the creation (depiction and description) and verbal delivery (presentation) of the CWS.
- Your entire CWS grade will be determined according to a "team presentation rubric" (see below) that will be made available to you well in advance of your presentation date.
- NOTE: Slackers beware! If there is sufficient evidence to suggest that a team member(s) is not pulling his/her weight, the professor reserves the right to grade this individual separately. In other words, an individual's substandard performance will not adversely impact his/her CWS team as a whole

PROJECT GRADING :

Your presentation will be graded according to a rubric whose four components (logos, pathos, ethos, kairos) are known as the "rhetorical modes of persuasion" first articulated by the philosopher, Aristotle. This system emphasizes how effectively a speaker appeals to his/her audience – how persuasive he/she is in "winning the audience over".

GOOD LUCK!