In 1997, the British Council commissioned an investigation into the global trends of English language usage. *The Future of English?* (Graddol: 1997) describes a world where native English speakers are becoming a minority to speakers of English as a second or foreign language. In 2006, Graddol wrote *English Next*, which explores how students worldwide are learning subjects through the medium of English as a foreign language, how English language teachers are becoming redundant, and how English is becoming more of a key life skill rather than a subject to learn for the sake of learning. Out of this global movement has emerged the umbrella term Content and Language Integrated Learning (CLIL), which means teaching a subject, such as chemistry, through the medium of a language other than that normally used.

This article looks at the implications of these trends for teaching and learning chemistry through the medium of English as a foreign language. First, the article investigates the language of chemistry based on chemistry curriculum materials and lesson transcripts. Then it describes approaches to teaching chemistry as a language. Next, the article provides suggestions for designing chemistry-related tasks that both support and develop this language in the chemistry classroom. The article concludes with a discussion of the implications of the CLIL approach as it relates to the education of chemistry teachers and the development of chemistry curriculum materials worldwide.

The Language of Chemistry

Carrasquillo and Rodriguez (132: 2002) spell out the challenge to chemistry teachers who work with learners through English:

*Science is, in itself, a language and each different science (biology, physics, chemistry) is a separate language.*

If chemistry is a language as well as a body of content, then it needs to be taught as a language as well as a body of content. So, what is the language of chemistry?

Kelly (forthcoming) describes three areas of language for any classroom context: subject-specific language, general academic language, and peripheral language. He states that an awareness of these “languages,” as well as a pedagogy for dealing with the language, is important for the science teacher working with learners in an additional language. Subject-specific language in chemistry can best be described as the information carrying words, which are usually noun phrases such as *sulphuric acid* or the *process of acidification*. General academic language is cross-curricular language and, as such, is not exclusive to any one subject. A good example is the language of sequencing, including phrases such as *first, second, next,* and *finally*. Such language is used in chemistry for introducing steps in a process, but it could also be used in a history lesson for describing reasons contributing to an event which happened in the past. Peripheral language is the language of the classroom: the language used by the teacher to manage the class and the informal language between students.
Clearly, subject-specific language is important for learning any subject. This paper suggests that when learning chemistry in an additional language, learners may need increased exposure to the general academic language in chemistry and classroom time invested in practicing that language. Teachers may need to rethink how they provide opportunities for learners to process the input and practice the output of the chemistry language. Learners may also need more opportunities to think about concepts in the foreign language as well as time to internalize the formal language, express it in their own words, and translate their own words back into the formal language of chemistry.

**Focus on a Chemistry Lesson**
The data and impetus for this discussion come from a 45-minute secondary-school chemistry lesson in a German Grammar School delivered through the medium of English. The students, who are 14 and 15, are just starting to study chemistry through English and their chemistry teacher is also the English teacher. The lesson has students observe a laboratory experiment in which sulfur is burned and made to react with water to produce sulfuric acid. Students then write up a protocol based on their observations.

There are 10 distinct didactic activities observed; each with specific chemistry language demands.

1. Students describe an illustration of the process through which acid rain is formed.
2. Students write the names of laboratory instruments on worksheets.
3. Students (and teacher) say the names of objects aloud.
4. The teacher describes the purpose of laboratory instruments.
5. Students (and teacher) describe substances.
6. Teacher describes steps in the experiment.
7. Teacher asks closed questions and students give answers.
8. Students write up their protocols of the experiment.
9. Two students draw instruments and label them at the board.
10. Students read aloud from their experiment protocol.

In summary, students are asked to reproduce the language of process description. They are expected to identify and name, in spoken and written form, objects used in a laboratory experiment, describe the purpose of the objects, and describe the appearance of chemical substances. Students are asked to listen to the teacher’s monologue description of an experiment and they are also expected to describe themselves, in spoken and written English, the sequence of an experiment in the form of a protocol, including what happens at each stage.

As shown in figure 1, the general academic language of this chemistry lesson corresponds to specific science thinking. By identifying thinking areas and language functions in this way, we can begin to create a plan for the language of chemistry lessons (Smyth, 2003). It is this kind of lesson planning that is a new challenge to chemistry teachers working with learners for whom English is an additional language. Teachers who normally busy themselves with the content of their subject now need to plan for the language issues that may arise in their classes. Teachers themselves provide much of this language, though it may not be made explicit in the way that some learners need it to be.

*Figure 1: The Language of Chemistry.*
Textbooks, curriculum guidelines, web-based materials, and electronic materials such as CD-ROMs all present sources for chemistry specialists to begin analyzing what terms their students need to study in English.

Figure 2 shows a curriculum document for a science course from Malaysia. This is a useful summary of the thinking that goes on in any science context. What is missing in this curriculum is the language of chemistry.

University students and teachers already benefit from an extensive study conducted in 2010 called the Academic Word List, which words appear with the highest frequency in English-language academic texts. (Coxhead, 2010). What is desperately needed today to support the growing population of second language learners of chemistry is a similar study of the language of chemistry for English-language chemistry courses. Based on this study, publishers could adjust their curriculum materials for this target group. Fortunately, as of the writing of this article, this is just beginning to happen.

**Teaching Chemistry as a Language**

Ball (2008) lays out a practical approach to content learning that respects learner variables in terms of language, concepts, and procedures. Kelly (2009) describes three dimensions (linguistic, conceptual, procedural) to content learning in a diagrammatical framework that enables the teacher to ask questions of students to...
plan opportunities for them to learn.

Chemistry teachers who are not experienced in dealing with language issues in their classrooms need immediate access to compilations of techniques for developing language in the science classroom. One such freely available resource is Content and Language Integrated Learning (Kelly, 2006). Wellington and Osborne (45: 2001) offer a very useful list of suggestions for developing science reading skills, called DARTS (directed activities related to texts).

Some examples of language-supportive chemistry activities include the following: using diagrams to guide listening to teacher monologues and note taking; using charts while reading chemistry texts to transfer information from linear to diagram form; having students find missing chemistry information by talking to a partner; using scaffolds for chemistry writing such as writing frames, substitution tables, and word lists based on models; and learning chemistry vocabulary through unit word maps to show logical links.

Implications for Chemistry Teacher Training and Curriculum Publications

Although it is still very hard to find books or other resources written specifically for students learning a science subject through an additional language, one noteworthy exception is Macmillan’s Vocabulary Practice Series Science (Kelly 2008). The VPS Science publication is based entirely on language analysis carried out using secondary science curriculum textbooks and materials (Chung-Harris, 2005). Gibbons (2002) provides teachers with a rich collection of ideas for “scaffolding” the language and the learning of content curriculum material. Clegg (1999: 71) argues for materials that subject teachers have “produced, or even in rare cases published, with language demands in mind.” Clegg also states the importance “for English teaching to be integrated as fully as possible into the teaching of the mainstream curriculum both in the early years” and further on in school (1999: 77). There are implications for textbook writers and publishers to pay attention to learner needs in chemistry as a foreign language. Clegg (1999: 120) lays out approaches to task design in the bilingual secondary classroom where there is a “need to balance the language and cognitive demands of the lesson, focusing on discourse functions and exploiting diagrammatical representation of content to the full.” The suggestion is that textbooks for this group of learners have language made explicit on the page and that the content be delivered to them in a largely diagrammatical form.

Hayes Jacobs (2006: 38) describes the need for an active literacy across the curriculum where subject teachers “talk about” language with their students. This is not to suggest by any means that chemistry teachers become language teachers in the traditional sense that we know. It may be, as Hayes Jacobs suggests, that chemistry teachers of the future will have moments in their lessons in which they make explicit to learners the different types of terminology in the lesson. These might include words that are “high frequency” in chemistry, terms that are “specialized,” and phrases that students can use to “embellish” their chemistry language.

Conclusions

It seems clear that a radical change is required in the way teachers are prepared for teaching chemistry when they are expected to work with children and students who are learning through English as an additional language. It is a move from the subject to the learner and from the content to the language of the subject.

*It is through language, communication, and real-life contextualization of*
Perhaps it also time to rethink efforts aimed at popularizing chemistry. It is through language, communication, and real-life contextualization of chemistry that we will make chemistry meaningful to young people. In an environment where growing numbers of young people demand chemistry in English, we should embrace an approach to popularizing the subject that involves communicating to young people through their own life experiences. The International Year of Chemistry in 2011 is a perfect opportunity for the chemistry community to engage with young people through intercultural communicative learning moments based within chemistry contexts. The IUPAC Young Ambassadors for Chemistry project, which ran from 2004 to 2007, is a good example of chemistry activities that engage young people through their own life experiences using the medium of a common language.

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*There are many examples where this is happening. The EU identifies CLIL as a priority educational strategy. The Spanish Bilingual Education Programme recently graduated its first cohort of learners which started learning through the medium of English in 1996. These are children who went into year one to be taught science (among others) through English. Another national example is in Qatar where the Supreme Education Council has recently passed legislation to the effect that all children will eventually receive their science education through the medium of English. This move is not restricted to primary and secondary chemistry education. The number of British student applications for chemistry degrees at UK universities fell by around 30 percent between 1996 and 2008 while the number of non-UK English-learning student applications increased by roughly the same percentage according to Royal Society of Chemistry statistics.

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