*Science, Engineering & Education, 6, (1), 2021, 96-104*

# Teaching English for Specific Purposes to Chemical Engineering Students Using Bilingual Learning Materials

Tsvetelina Vukadinova[1]*, Senia Terzieva[2], Mladen Popov[2,3]

[1]*University of Mining and Geology "St. Ivan Rilski", Sofia, Bulgaria*
[2]*University of Chemical Technology and Metallurgy, Sofia, Bulgaria*
[3]*Institute of Molecular Biology „Roumen Tsanev", Bulgarian Academy of Sciences, Sofia, Bulgaria*

*Received 05 November 2021, Accepted 15 November 2021*

**ABSTRACT**

*The focus of this research is on improving the learning process and students' linguistic development in engineering courses by introducing and applying an innovative and alternative educational tool in bilingual environment. The participants in this study are 4th year students (bachelor program "Chemical Engineering") at the University of Chemical Technology and Metallurgy.*

*Keywords: bilingual education, English for Specific Purposes (ESP), engineering science, curriculum, knowledge acquisition, effective learning.*

## INTRODUCTION

The European Qualification Framework (EQF) and the National Qualification Framework (NQF) define the expected learning outcomes. Communication skills in the foreign (English) language are considered key requirements for all students. Being fluent in both written and spoken English is essential part of the professional characteristics of the successful engineers. The use of a special language is the foundation of all fields of science. The special language (English for Specific Purposes - ESP) is professionally oriented and provides relevant vocabulary in the selected area of work [1].

The teaching and learning design of engineering programs integrates improvement, training and performance of a set of competences, including communicative ones. The bilingual task environment is a sufficient way to enhance students' communication skills in a foreign language and support the learners in mastering specific engineering competencies. There are two main works in terms of educational goals in engineering education - Curriculum CDIO (Conceive, Design, Implement, Operate), and "Taxonomy of Engineering Competencies". Both present the goals of engineering education from different perspectives [2].

### CDIO

Leading motive for creating the curriculum is to find a solution to "how universities could contribute to quality education in technical

**Correspondence to: Tsvetelina Vukadinova, University of Mining and Geology "St. Ivan Rilski", 1 Prof. Boyan Kamenov Str., 1700 Sofia, Bulgaria, E-mail: tsvetelina.vukadinova@mgu.bg*

specialties while at the same time supervising engineering professionalism." The ambition is to close the "gap" between *engineering training* and *engineering practice* that emerged in the middle of the last century. Woollacott considers that lecturers in engineering education are related more to engineering science than to the requirements of the industry [3]. In the core of the CDIO is the belief that design is the essence of "engineering" [4 - 6]. It is important for every graduate to master the CDIO of engineering systems in today's modern world. Changes in strategies include expanding modules in all engineering curricula; reorganizing the curriculum in order to provide more opportunities for students to participate in project development and design projects; providing a practical part. CDIO tries to close the gap between engineering education and practice by reassessing engineering education from the perspective of modern engineering practice. Hence, it is important not to leave the students' foreign language needs in engineering courses out of sight. These are crucial for successful performing of all engineering work-related tasks and can be sum up as follows: skills for using professional and scientific literature and professional communication skills. In order to achieve those skills, the engineering students need education that helps them do well in other specialty-related learning tasks. This means, knowledge transfer is possible.

Enhancing language skills and competencies is significant in students' learning process with scientific terminology. In order to achieve the educational objectives, the lecturer is to design a clear frame in relation to teaching. The design has to answer four questions: **1. What**, **2. At what point**, **3. How** and **4. Why** is to be achieved in the course. To improve teaching and learning process, it is essential for the lecturers to work first on planning, developing, structuring and establish learning activities. Those activities ought to support learners in mastering spoken and written speech in a foreign language, as well as developing their ability to use the foreign language in real situations in order to achieve various goals in the professional environment.

**Taxonomy of Engineering Competencies**

Many researchers believe it is relevant to rewrite the predominant courses in the first year of study, to change and restructure the entire program [7 - 9].. There are two driving motives. *The first* one entails the nature and dynamics of the difficulties in the learning process that arise in the first year of study. In this case, we are talking about problems of teaching and learning. *The second* one involves the curriculum structure.

The improvement of academic competence must be at the forefront of the development of crucial non-technical professional competences. It is necessary to make a framework-description of what the competent engineer represents. Thus, a program can be designed to support the development of non-technical aspects of students' professional competence. The taxonomy (classification) was developed separately from the curriculum based on research findings [10]. The classification focuses on the engineering work and the competencies needed to perform it effectively. There is a difference between specific engineering activities and non-engineering ones. It is important to know where and how they "meet" to achieve a specific goal. The taxonomy describes the knowledge and skills necessary to perform these activities competently. The comprehensiveness, validity and reliability of the taxonomy are based on the scope and quality of competencies, as well as the quality of the theory and research results used in the formulation.

The curriculum and taxonomy represent a selection of educational objectives with a large volume and many details. The curriculum includes and describes more fully all points in the taxonomy. One of the strengths of taxonomy is its foundation in theory and literature. In addition, the curriculum includes most of the content of the taxonomy, which allows approval of the comprehensiveness, validity and reliability of the curriculum. Its format gives it the function of a valid document. It is suitable for easy transformation into expected results. The format of the taxonomy is more compact and descriptive, which makes it suitable for a descriptive document.

**The taxonomy** presents **engineering work** and distinguishes between three types of special engineering work (engineering analysis, design and research), clearly showing what is expected of engineers in different positions: analysis, design, testing, development, maintenance, sales, research, consulting, teaching.

**The curriculum** focuses on **engineering activities** and the necessary knowledge, skills and competencies related to the full cycle of the engineering product/system. Teamwork is extremely important and is recognized as a key skill in industrial environments [11].

The engineering field is developing extremely dynamically, which is dictated by the continuous technological progress. The focus is shifting to the specific requirements for engineers, and hence to how future professionals should be trained. Therefore, the curriculum needs to be updated periodically, and this update should be considered a permanent feature. Such a modification requires careful selection of educational goals. Therefore, it is very useful to have a universal and verified document with selected specific objectives. The curriculum is designed to be such a document: (Crawley "Creating the CDIO Syllabus, a universal template for engineering education" [4], and Berggren "CDIO: An international initiative for reforming engineering education"), [5]. The statement of educational objectives can and should frame the curriculum, as well as perform two main functions: to facilitate the definition of the expected results for certain curricula; to support each stage of the curriculum development.

**The curriculum** meets the first point by providing a curriculum for engineering training that is flexible and allows modifications to expected outcomes. It responds to the second point by providing an extensive and detailed register of study items.

**The taxonomy** is a classification of the required engineering competencies. It shows the whole picture as a descriptive document of what the work of an engineer involves. Three conclusions can be drawn from this: the universal document for the purposes of engineering training must correspond to the expected results and be a useful descriptive document for the development of the curriculum; the curriculum needs to be updated; the curriculum is subject to assessment and verification to what extent it meets the already mentioned requirements.

All this being said, it is essential to find the meeting point of engineering and non-engineering activities in order to achieve a specific professional goal. One efficient way to integrate foreign language for specific purposes in the engineering education (curriculum) is by applying the bilingual educational method.

## The Bilingual Teaching and Learning Experience

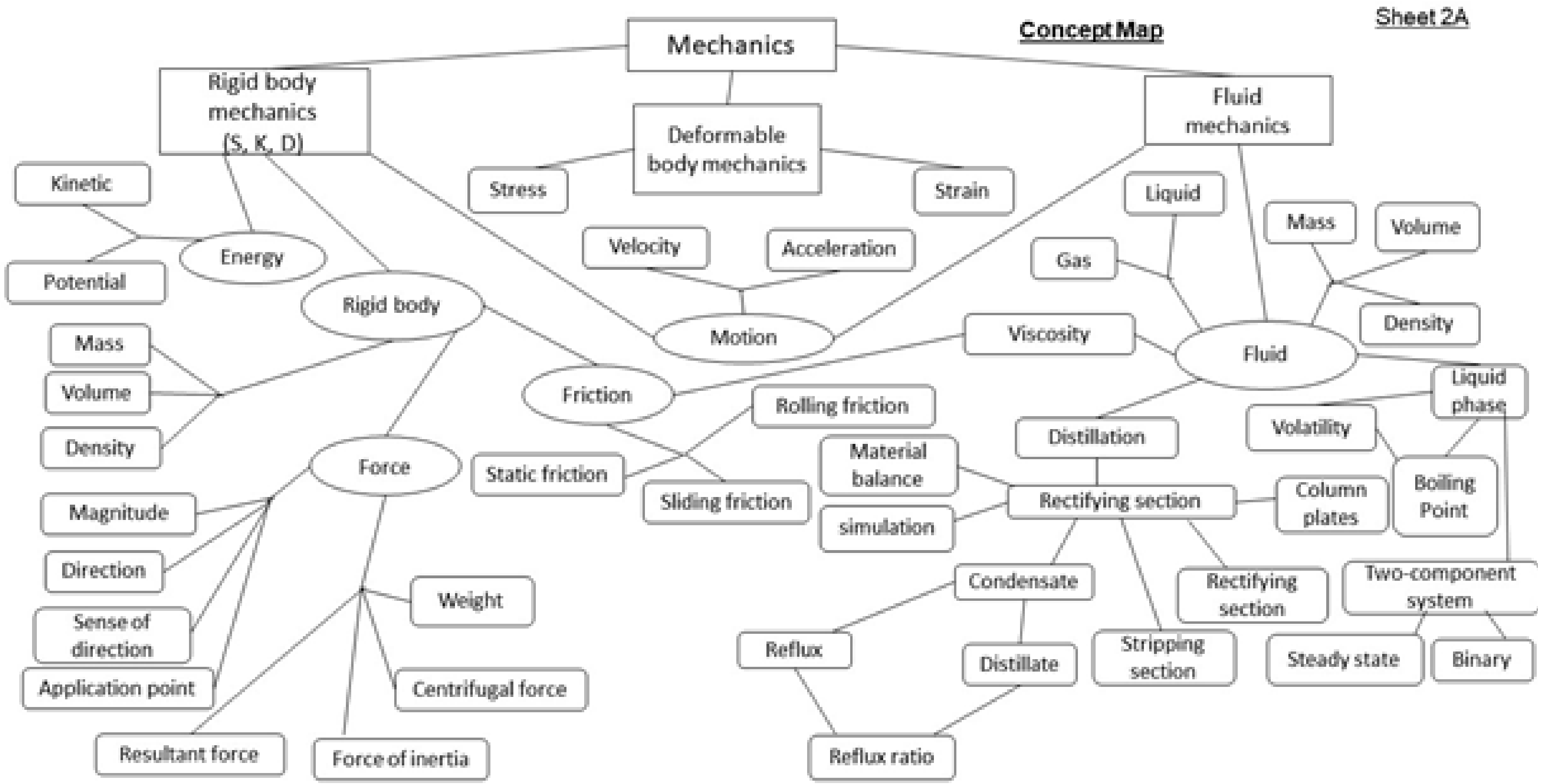
The bilingual educational method has long history in our country. It is applied mostly at Bulgarian secondary language schools. The method itself suggests integrating a foreign language into subject teaching. This approach is relevant to "any educational context subject to the dual objective of applying language learning in a language other than the learners' mother tongue for the purpose of teaching non-language content" [12].

Shopov points out the main characteristics of bilingual teaching [2], (according to Mentz, 2001):

- combining language teaching with subject content;

- mastering the subject content, a high level of proficiency in L2 and a good attitude towards the respective culture;

*APPENDIX 1. Concept map (bilingual in the research; here: in English).*



- implementing authentic situations and materials for teaching and learning purposes;
- integrating suitable methodology for the respective educational content.

## EXPERIMENTAL

The motive for conducting the present study and the appliance of the bilingual learning materials in the ESP class for the engineering students are teaching and learning issues at engineering universities.

The ESP lecturer in cooperation with the lecturer in the fundamental specialty "Chemical Engineering" developed the specific design of the teaching materials, which aim to guide students and meet their needs in the studying process of ESP in engineering specialties. These materials provide students with original scientific textbooks and tasks and support the learning process by submitting specific activities closest to the students' future professional commitments. A further characteristic of the teaching and learning materials is improvement of students' knowledge and communicative skills and competencies: the materials cover the implementation of engineering and non-engineering activities. Compounding the English language course and the selected engineering topics created the bilingual setting. **The teaching materials** consist of original texts from Chemistry textbooks, figures and formulas related to the specialized subject. This kind of texts give a clear understanding of the language use for special purposes and terminology in their natural environment. Part of the work and development process of the educational materials was the content analysis. It filtered the mostly used terms so they formed the diagram of logical relations of the terms, **concept map**, and the **glossary of terms** (each of them in both languages). Students had the opportunity to use those during the research in order to support their learning progress (see Appendix). The ESP lecturer along with the lecturer in the fundamental specialty developed these tasks especially for the research, and all of them are in English. They include different activities:

- simulation of process dynamics with the Berkeley Madonna software;
- reading and comprehension (original English texts);
- answering open questions (students write their own answers, which implies creating their own scientific text using specific terminology).

The research opens up with a presentation held in English by the lecturer in the fundamental specialty "Chemical Engineering". Students in their final year of studies are expected to have developed competencies and ability to take notes during listening to lectures in a foreign language. When the presentation has finished, students work on specific tasks. The participants' feedback on the experimental bilingual materials in the questionnaire best show why those materials are convenient for the students, how they help them enhance their knowledge and language skills, support the learning process and knowledge acquisition in the course, and improve significantly Chemical Engineering training (see Appendix 1 and Appendix 2). The aim is for the bilingual materials to be applied long-term in the foreign language / ESP class. The students' feedback given on the work with the Appendix 1 and Appendix 2 is presented on Figs. 1 and 2.

APPENDIX 2. Glossary of terms (bilingual in the research; here in English).

**1**. **Binary** – relating to, composed of, or involving two things.

**2. Boiling point** – the temperature at which water becomes a gas.

**3. Column plates –** they are metal barriers in plate distillation columns, which are intended to retain some of the downward fluid and to provide good contact with rising vapor. Mass and heat exchange between the liquid and vapor phases is carried out on the plates.

**4. Condensate –** the completely condensated vapors that have left through the rectification section of the column.

**5. Distillation** – a way of separating a homogeneous liquid mixture into its constituent parts based on the various volatility of its constituent parts.

**6. Distillation column** – apparatus in which the process rectification is carried out (continuous distillation with reflux process)

**7. Liquid phase** – a homogeneous part of a heterogeneous system, separated from the other homogeneous parts of the system by a boundary surface.

**8. Material-Balance (mass and component)** – the appliance of the law of conservation of mass to the analysis of physical systems.

**9. Overhead product** – portion of condensate leaving the system as end product of the process.

**10. Rectification** – continuous distillation with reflux.

**11. Rectifying section** – the trays between the feed tray and the top of the column. In the rectifying section, the aim is to concentrate the lighter component in the vapor phase.

**12. Reflux** – portion of condensate that is returned back to the column.

**13. Reflux ratio** – ratio between reflux flow rate and the flow rate of the overhead product.

**14. Simulation** – conducting computer experiments with mathematical models of complex real-world systems. Because computer experimentation is performed with a system model rather than a real one, simulation is a powerful tool for exploring systems with which it is not possible or ineffective to perform real experiments. The purpose of the simulation is to reveal the properties and regularities of the studied system, to make generalizations, conclusions and predictions, to solve practical problems.

**15. Steady state** – a state where the characteristics of the system do not change over time.

**16. Stripping section** – the trays between the bottom of the column and the feed tray.

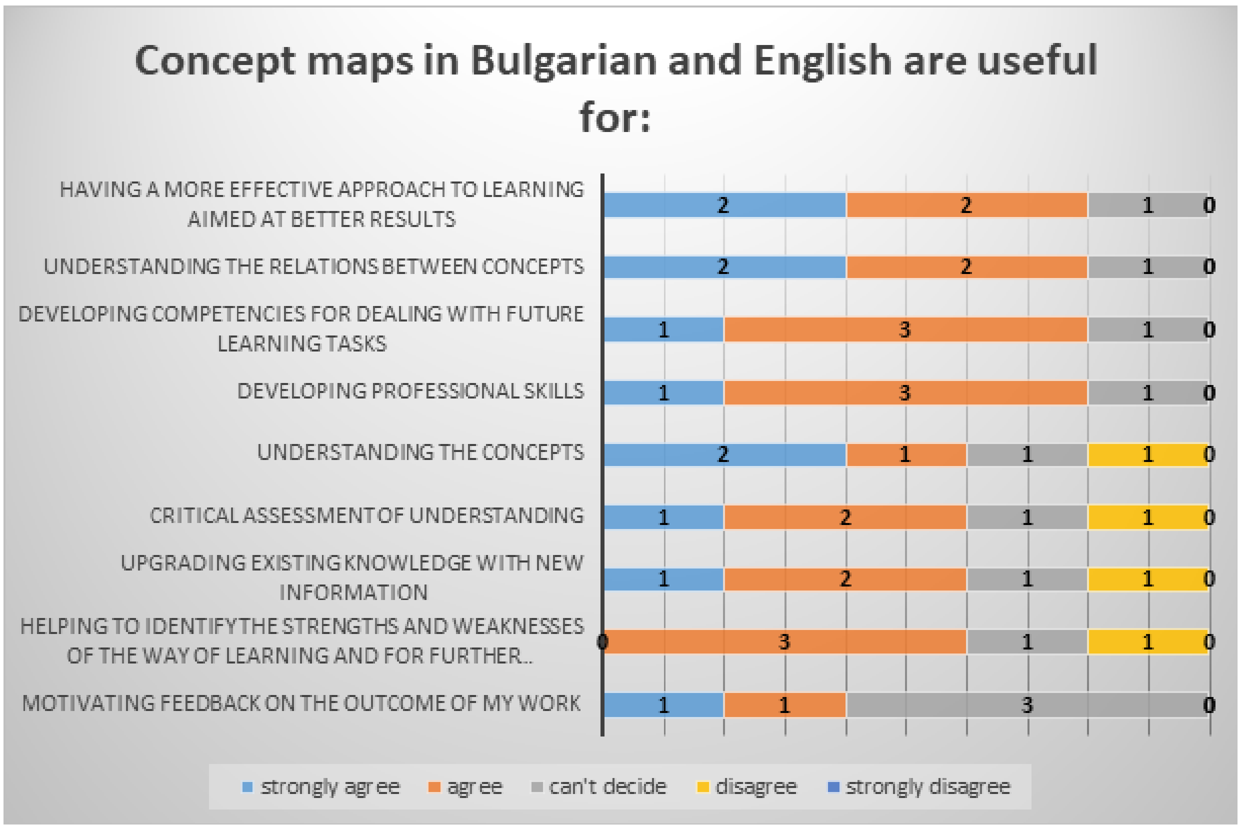



Fig. 1. Students' feedback on their work with concept maps.

**17. Two-component system** – a system consisting of two components.

**18. Volatility** – the ability of liquids to evaporate, to move from a liquid to a gaseous state.

Students in their final year of Bachelor studies consider the application of concept maps useful for a "more effective approach to learning towards better results", but also for "understanding the relation between concepts". Here, all statements have a large number of affirmative answers. It is obvious that the students give excellent feedback on the benefits of the use of concept maps and integrating them into specialized foreign language teaching.

In the first place, with a full number of positive answers, is the statement that working with educational content in native and foreign languages makes easier understanding of the meaning of concepts possible. Next follows the statement that this way of working "makes the content of the course more appealing to learn." With the same number of positive answers is the statement that working in a bilingual format gives "motivation to learn". Evidently, the hypothesis that working in a bilingual environment is more effective and motivating for students and that they are "willing to continue learning a foreign language" and "seeking more information from the specialty in a foreign language" has been reaffirmed. This way of studying gives students "the opportunity to establish relations between knowledge of the native and the target language." The last statement, which received the least affirmative answers, concerns "self-assessment of current professional abilities". For the majority it is not valid, but some students recognize it as true for them.

## CONCLUSIONS

The bilingual learning materials help students develop a more effective learning approach that aims better results and development of professional skills. In addition, they help students

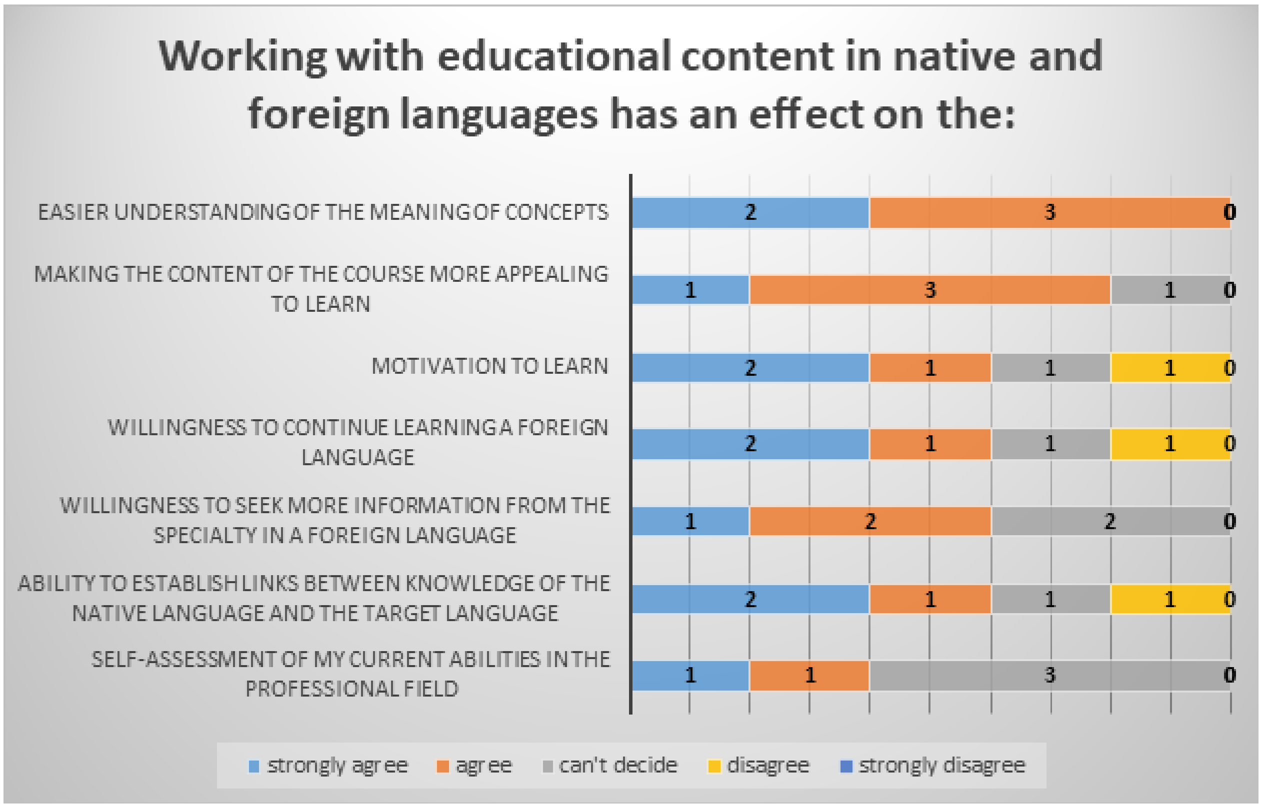



Fig. 2. Students' feedback on working with bilingual educational content.

establish and understand the connection between concepts and recall what they have learnt in the past, but also help them learn the new information and apply the meaning of concepts. Working with bilingual content leads to better understanding of the meaning of the concepts and makes the course content more appealing to learn. This surely motivates the students, which leads to better results and automatically points out the significance of the bilingual materials supporting the implementation of future professional duties.

## REFERENCES


1. T. Hutchinson, A. Waters, English for Specific Purposes: Learning-Centered Approach, Cambridge: Cambridge University Press, 1987.
2. T. Shopov, Pedagogy of Language. Sofia "St. Kliment Ohridski", 2013.
3. L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences, University of the Witwatersrand, Johannesburg, South Africa, Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007, http://rocketship.cdio.org/
4. E.F. Crawley, Creating the CDIO Syllabus, a universal template for engineering education, 32nd ASEE/IEEE Fronteirs in Education Conference, Nov 6-9, 2002, Boston, (see also www.CDIO.org). In: L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences, University of the Witwatersrand, Johannesburg, South Africa, Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007.
5. J. Bankel, K. Berggren, K. Blom, E. F. Crawley, S. Ostlund. The CDIO Syllabus: A comparative study of expected student proficiency, European Journal of Engineering Education, 28, (3), 2003. In L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences, University of the Witwatersrand, Johannesburg, South Africa, Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007.
6. J. Grimson, Re-engineering the Curriculum for the 21st Century, European Journal of Education, 27, (1), 2002, 31-37. In: L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences, University of the Witwatersrand, Johannesburg, South Africa, Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007.
7. L.C. Woollacott, From Academic Development to Student Development: A Scenario for a Transformed Curriculum in South African Engineering Education, Proceedings of the 3rd African Regional Conference on Engineering Education, Pretoria, September, 2006, 329-340. In: L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences. University of the Witwatersrand, Johannesburg, South Africa. Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007.
8. L.C. Woollacott, D. Snell, "A Re-Conceptualization of Engineering Education Based on Situated Learning Theory", Proceedings of the 3rd African Regional Conference on Engineering Education, Pretoria, September, 2006, 141-152, In: L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences, University of the Witwatersrand, Johannesburg, South Africa, Proceedings of

the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007.
9. G. Gibbon, K. Nixon, M. Nixon, Analyzing the raw material: Who are our first years? Proceedings of the 3rd African Regional Conference on Engineering Education, Pretoria, September, 2006, 399-407, In: L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences, University of the Witwatersrand, Johannesburg, South Africa. Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007.
10. L.C. Woollacott, Dealing with Under-Preparedness in Engineering Education: Part 1: Defining the goal: A taxonomy of engineering competency, 2003 WFEO/ASEE e-Conference, http://www.asee.org/conferences/e-conference/papers/Eng Competency final.pdf. In: L. Woollacott, The Goals of Engineering Education: a Rationale for a Universal Document based on the CDIO Syllabus and the Taxonomy of Engineering Competences, University of the Witwatersrand, Johannesburg, South Africa. Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007.
11. M.J. Riemer, English and Communication Skills for the Global Engineer. Global J. of Engng. Educ., 6, (1), published in Australia, UICEE, 2002, 91-100. http://www.wiete.com.au/journals/GJEE/Publish/vol6no1/Riemer.pdf
12. D. Marsh, CLIL/EMILE in Europe: Emergence 1958-2002, The European Dimension, Actions, Trends and Foresight Potential, Finland, 2002.