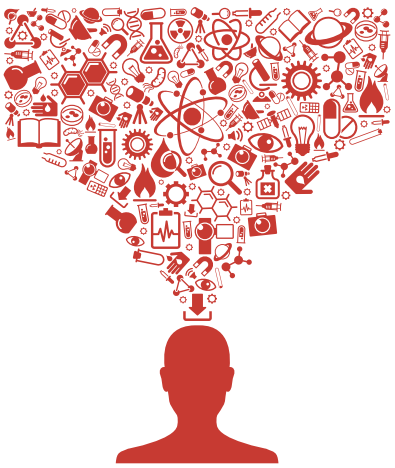
International Comparisons of Tertiary Chemistry Education

A Best-Practice Approach for Development and Quality Enhancement

by Maja Elmgren, Felix Ho. and Eva Åkesson



There are many reasons chemistry education varies among nations and institutions: cultural traditions, societal expectations, socio-economic factors, and educational resources, to name just a few. At the university level there is also a dependence on the earlier educational system, as well as the research profile of the particular institution. In an increasingly globalized world, however, graduate mobility across international boundaries is more relevant than ever. In order to promote high quality chemistry education, comparisons and communication at both national and international levels are important for designing or improving programs. Such comparisons can raise the awareness of what to change and what to hold on to.

In an IUPAC project supported by the Committee on Chemistry Education (CCE), ten partners across seven countries developed a process-focused method designed for learning by sharing and comparing chemistry programs (Elmgren et al. 2014). During the project, new perspectives and shared knowledge were used for inspiration and awareness of differences. In this endeavor the multicultural composition of CCE has been valuable, both to form a diverse task group and for feedback when planning the project and during the development and evaluation of the method. An overview of this international project is presented here, from the project's inspiration to the design and implementation of tools for conducting informative and meaningful comparisons across educational programs, and finally to an assessment of the project outcomes and implications for the future development and improvement of chemistry education at the tertiary level.

Inspiration from national comparisons

The project emanated from a national initiative involving three Swedish universities (Åkesson et al. 2008). The purpose of the collaboration was to enhance the quality of chemistry teaching by sharing and comparing the changes resulting from the so-called Bologna process, under which European countries that are signatories to the Bologna Accord undertook to harmonize higher education qualifications in their respective countries (more information about the Bologna process can be found at www.ehea.info).

The Bologna process brought about numerous changes to the Swedish Higher Education Act and the Higher Educational Ordinance. New degree descriptions, based on intended learning outcomes related to the Qualification Framework of the Bologna process, were decided upon. This was the starting point for an intensive activity at Swedish universities in which intended learning outcomes were formulated for educational programs as well as for courses/modules.

Intended learning outcomes are statements of what a learner is expected to know, understand, or be able to demonstrate after completion of a process of learning (e.g. module, course, degree program). An example of an intended learning outcome from a course syllabus states that:

> "On completion of the course, the student should be able to choose appropriate experimental methods to determine reaction rates and apply this knowledge to relevant problems."

A key characteristic of learning outcomes, in contrast to keyword lists of topics and course content covered by the course, is that they extend the perspective from the content of the course to the variety of skills and competences that the students will need in their future lives. Learning outcomes place the focus on the student and what he or she will learn and achieve during the course, rather than on what the teacher will teach during the course. This facilitates discussions and considerations of alternatives to the current practice, with the focus not just on factual knowledge, but also on competencies and skills.

The national project made use of the growing interest in specified and written intended learning outcomes

to analyze chemistry programs in their entirety. The progression from the first course to the final degree thesis project was discussed, and the development of various scientific skills before and during the degree project was emphasized in particular. The new curricula and intended learning outcomes were compared as a part of the review process. Even more important were the various workshops held during the project, where many teachers met to discuss and compare chemistry education at their respective universities. A simple matrix for the comparison of intended learning outcomes was used. This was found to be useful to elucidate both anticipated and incidental differences during these workshops. It was, however, just a part of the comparison, and during the project new ideas on learning activities and assessment were discussed.

The conversation climate was strikingly open and constructive during these workshops. There were enough teachers from each university to give a broad spectrum of the education program without the need for any particular person to take responsibility for every aspect. At the same time, there were many possibilities for critical discussions and new ideas. The teachers emphasized positive aspects, rather than negative; when they found something valuable at another university, they were inspired to accomplish something similar. When, on the other hand, they could inspire others, they were gratified and wanted to stimulate further development elsewhere. Discussions about funding reductions or perceptions of falling student standards, which could otherwise be put forward as reasons not to engage in development work, were put into the background.

The experiences from this national project gave inspiration for an international project that could widen the perspective far beyond national boundaries.

International comparisons for overview and outlook

The main intention of the international project was to build upon the experiences and insights from the national project and explore ways to enhance chemistry education through sharing insights. To enable the process, potential international collaborators were contacted and a project proposal was submitted to the IUPAC Committee for Chemistry Education. Intended learning outcomes were again the means through which the international comparisons would be made, using the outcomes articulated in overarching regulatory and policy documents at international and national levels, in degree program curricula at the university/institutional level, and in individual syllabi at the courses/modules level. Consistency between learning outcomes across the different levels was assumed to be essential, and ideas from different parts of the world could give inspiration. In addition to comparing learning outcomes, we investigated the coherence between learning outcomes, learning activities, and assessments within each institution (also known as constructive alignment), making use of the range of ideas and experiences in the international participant composition. This was grounded in the idea that students need to learn and practice through suitable learning activities, and they will value these more if the teachers themselves value them in their assessments. By contrast, intended learning outcomes, no matter how well formulated, will have hardly any practical value if they are not constructively aligned with learning activities and assessment.

The comparing and sharing process

The main analysis took the form of two consecutive workshops with participants from the USA, Australia, Finland, France, Germany, the Netherlands, and Sweden. The overall project design was discussed during a workshop in conjunction with the International Conference on Chemical Education in Rome 2012. Following that workshop, a matrix comparing the overarching documents from the USA (ACS guidelines), Europe (Eurobachelor), and Australia (Learning and Teaching Academic Standards) was constructed. A tool for self-analysis was also fashioned incorporating these comparisons.

A second workshop (in conjunction with the IUPAC General Assembly in Istanbul 2013) was dedicated to discussion and further analysis, and the overarching documents were also discussed. Using the tool for self-analysis, workshop participants continued on to the degree curriculum and course/module levels, analyzing documentation from their respective institutions at the bachelor level. The heavy emphasis on discussions and critical analysis that took place between participants was important to the process both at and between these workshops. The comparative approach across and within the borders of educational systems was crucial for developing a “best practice” process that can be applied more widely. The vivid discussions also enabled continuous evaluation and development of both the tool and the process itself.

The utility of the tool was probed in an open workshop at the IUPAC International Conference on Chemical Education 2014 in Toronto. It was clear that

educators who had not taken part in the first phase were nevertheless perfectly able to use the tool. The process and the tool for self-analysis enabled the workshop participants to lift the discussion about learning outcomes to a higher level of abstraction. At the same time, specifics such as the learning activities actually employed and details of assessments still had a place. The workshop concluded with discussions on how to use the insights gained to make real changes to enhance student learning, in which the participants expressed that the tool would make it easier to discuss important issues at their respective institution.

Findings from the comparison process

While the first impression of the overarching documents at international and national level was very disparate, these differences were upon closer examination found to be more in style than in content. This was partly due to the learning outcomes being clustered in different ways in the different documents, or as in the case of the ACS guidelines, other useful ideas on chemistry education being mixed in with intended learning outcomes. In addition to that, different documents placed different emphases on the different competencies and skills. An example regarding ethics can illustrate the variation: while the ACS guidelines state that "Students should conduct themselves responsibly and be aware of the role of chemistry in contemporary societal and global issues", the Eurobachelor simply stated "Ethical commitment" without further elaboration.

Overall, the three documents through their different emphases gave broader perspectives on chemistry education, but on the whole a fairly homogeneous picture emerged from the Euro-American-Australian part of the world. The analysis of the overarching documents was found to be a suitable starting point in the following collegial discussions on the chemistry bachelor, and no major competencies were identified to be absent in all documents. It should, however, be noted that the perspectives from the rapidly growing economics and developing countries were missing, and that important issues are needed for further refinement and adaptation.

The contents of intended learning outcomes for the bachelor degree from the different institutions were also quite similar, and in line with the overarching documents. The tool and the process were, however, important for highlighting some blind spots and to reflect on expressions.

At the module/course level the variation of intended learning outcomes was larger. In some cases the comparison and discussion process revealed a lack of progression and omitted competencies. The self-analysis also unveiled some weaknesses in assessment, especially regarding generic or "soft" skills (such as scientific communication, leadership skills, ethical and societal considerations etc.). Here the first-hand knowledge from the participants, and interactions and discussions between them, were critical to reach beyond the wording of the documents, to gain insight about to what extent the documents reflect actual practice. It seemed that assessments and learning activities vary more widely than the intended learning outcomes, and much could be learnt from comparing practical realities. This comparison was found to be easier to perform starting from intended learning outcomes, giving first an overview of what the learning activities and assessments are meant for.

For a thorough description of the results, we refer to the article by Elmgren et al. (2015)

Implications and future development

Many university teachers across the world are trying to improve chemistry education. As a part of that, they might discuss the most important skills and competencies for students to acquire and how to let those direct the improvement of intended learning outcomes, learning activities and assessment in courses or modules. This is a great challenge, and our workshop format has proved useful, facilitating participants to take advantage of the effort that has been done by others in developing effective curricula. At the same time it is essential to take local considerations into account, and not try to copy, but critically evaluate the benefits of different setups for the students in the particular setting.

The process-focused method, developed in the project, can be used for tackling and understanding the relationships between learning outcomes at different levels across institutional and national boundaries. Instead of prescribing a certain set of intended learning outcomes, learning activities and assessment, we aim to assist the chemistry educator to navigate through the variety of documents for quality enhancement of their courses and education programs.

In line with this, the tool developed in this project would be best used in combination with discussions, either amongst colleagues from the same institution, from other institutions, and/or various stakeholders including current and former students

(continued on page 31)