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Implications of mass education on chemistry higher education

Christine O'Connor
Dublin Institute of Technology

Designing curriculum and assessment to promote effective learning in chemistry in higher education

Christine M. O'Connor

Abstract

This paper is an overview of current issues for academics designing programmes for third level education in chemistry. The changing demographic of third level students along with employers' demands has resulted in course development with a focus on skills (Hyslop-Margison 2001) to support a knowledge-based society. These factors inevitably have an impact on curricula and pedagogies. In this paper the rationale behind contemporary changes in curriculum design is introduced together with a discussion of curriculum design models, assessment models and evaluation models. Examples of innovative curricula and assessment models in third level chemistry education are incorporated throughout the paper.

Introduction

Current chemistry education is in a dynamic state as third level institutions are under pressure to fulfil the economic demands from industry, as well as attracting prospective students to their programmes from the ever decreasing pool of chemistry second level graduates (Childs 2002). Current chemistry programmes in Ireland are becoming more career focused than before, and the transferable skills acquired during the programmes are now used as marketing tools for prospective students. The change in career-focused curricula design may be a way forward. However, the question that needs to be asked is: Is the content knowledge being lost by our current students? A 'need to know' attitude is being experienced by academics from the students as they frequently ask 'What do I need to know?'. This question, theoretically, should be answered by the list of learning outcomes of the curricular documents and module descriptors, and the delivery mechanisms and assessment strategies (Biggs 1999) in place, ideally, should reinforce the intended learning outcomes. A structural guide to standards of knowledge, skill or competence, to be acquired by learners has been published by the National Qualifications Authority of Ireland (NQAI) and the European Credit Transfer System (ECTS) is being implemented as part of the Bologna process. Since the ECTS is designed to be a student-centred system, based on the student workload required to achieve the learning outcomes and competences to be acquired, why are we still being asked ‘What do I need to know?’.

Designing curriculum and assessment strategies for third level education in the twenty-first century has drastically changed from that of the past. Since 1975 education researchers have witnessed a shift in focus from the curriculum to the student (Bucat 2004).

> OECD economies are placing an increasing emphasis on the production, distribution and use of knowledge. The knowledge economy is dependent on people’s ability to adapt to situations, update their knowledge and know where to find knowledge. These so called knowledge workers are being paid for knowledge skills rather than manual work.
>
> (Maier and Warren 2000)

The past 100 years saw the dominant influence in the curricula structure as being that of the academics in their separate knowledge fields. Barnett (2000) states that ‘in the contemporary world, academic hegemony is dissolving as curricula become subject to two contending patterns of change’. The two patterns of change suggested by Barnett are: (i) widening of participation at third level colleges and (ii) an emerging universal shift in the direction of performativity. What counts is ‘less what individuals know and more what individuals can do (as in their demonstrable skills)’. He goes on to say that ‘curricula are taking on ad hoc patterns that are unwitting outfall of this complex of forces at work, diversifying and universalising. He feels that as a consequence, curricula will be unlikely to yield the ‘human qualities of being that the current age of supercomplexity requires’.

Bodner (1992) stated that ‘changing the curriculum – the topics being taught – is not enough to bring about meaningful change in science education, we also need to rethink the way the curriculum is delivered’. Bucat (2004) proposes that ‘Before our teaching can advance, we need to be knowledgeable not only about the learning outcomes of our teaching, but of the conditions, including subject specific factors, that have given rise to those outcomes. Then perhaps we can design our teaching accordingly'. The dramatic changes which have been taking place in higher education in recent years and the consequential disruption to the 'traditional identities of place, of time and of scholarly and student communities' is changing the structure and functions of third level education institutions. The changes are producing for the twenty-first century a higher education system that operates under a greater variety of conditions than ever before (part-time/full-time, work-based/institution-based, face to face/delivered at a distance, etc.) and which brings with it a student experience and an informal curriculum, which are both changed and increasingly diverse. Competing epistemologies are struggling to shape the formal undergraduate curriculum of the twenty-first century: the deconstruction of the subject, as reflected in, for example, the modularisation of the curriculum; the cross-curricular 'key' skills movement, the learning through experience movement and the shift of the seat of learning outside the academy; the profoundly disruptive potential of web-based learning. (Bridges 2000)

In order to approach the challenges of the diversifying educational demands in third level institutes the role of curriculum design and assessment strategies will be discussed in the remainder of this paper and some evaluation techniques suggested.

Curricula design

Chemistry is regarded as a difficult subject and many of the concepts are inexplicable without the use of analogies or models. Reviews of misconceptions over the past 16 years will affirm this (Andersson 1990; Gabel and Bunce 1994; Nakhleh 1992). Recent modifications in chemistry education have seen the introduction of modularisation. The introduction of the modular system has been a quick transformation and perhaps with little time for forward planning and inadequate prior knowledge of the importance of programme learning outcomes.

> Planning for learning means that designing the forms of instruction which support learning becomes as important as preparing the content of programmes.
>
> (Dearing 1997)

Many of the programmes currently modularised are a dissected version of the 'unmodularised' course with all the content, and less delivery time and formative assessment due to semesterisation. If we look closely at the current curricula of our programmes, are they 'The planned and guided learning experiences and intended learning outcomes, formulated through the systematic reconstruction of knowledge and experiences, for the learners' continuous and wilful growth in personal social competence' as defined by Tanner and Tanner (1980)? An example of a curriculum design model is given in Figure 1 which gives a simplistic overview of where to start. The level of award which the programme is to acheive can be selected in accordance to the NQAI. Level 7 is a B.Sc. (Ord), level 8 is a B.Sc. (Hons) and level 9 is M.Sc., and so on. The next step is to decide on the programme aims and objectives in the form of learning outcomes specific (i) to the programme and (ii) to the individual modules.

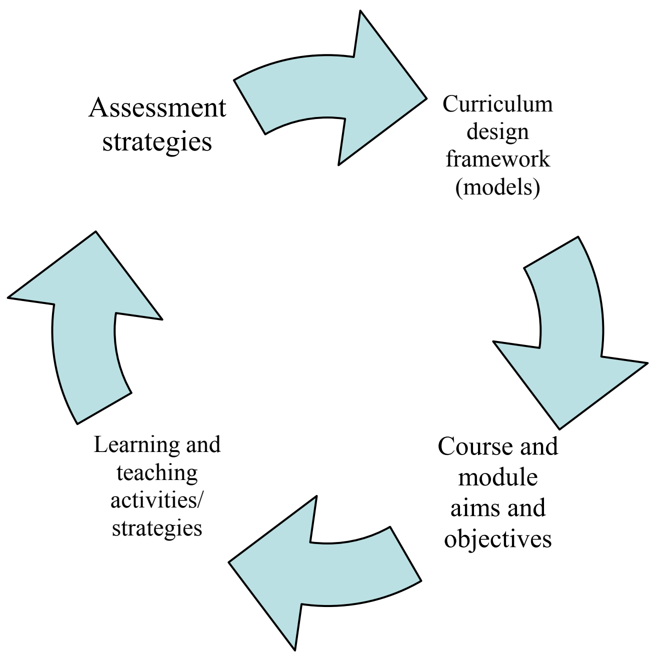

Figure 1: Example of a curriculum design model

The learning outcomes should reflect the skills and competences required of the graduate from this programme. Learning and teaching activities should be selected that are suitable to the delivery of the module (Bucat 2004). Activities is the 'key' word as 'Learning takes place through the active behaviour of the student: it is what he/she does that he/she learns, not what the teacher does' (Tyler 1949). In an integrated system where assessment is constructively aligned to drive the learning

(Biggs 2002), this approach to curriculum design optimises the conditions for quality learning.

When designing a new programme a curriculum planning model may be used to oversee the programme design as shown in Figure 2. This gives the programme manager and committee a prospective view of the programme as a whole and the criteria that must be fulfilled in order to implement it successfully. Fink (1999) has outlined five principles to ensure good course design. These include criteria such as:

1. challenging students to higher level learning;
2. using active forms of learning;
3. giving frequent and immediate feedback to students on the quality of their learning;
4. using a structured sequence of different learning activities;
5. having a fair system for assessing and grading students.

The last criterion is an important one, as the increased diversity of learners has changed from the traditional students of the past, and this diversity must be catered for within the programme design.

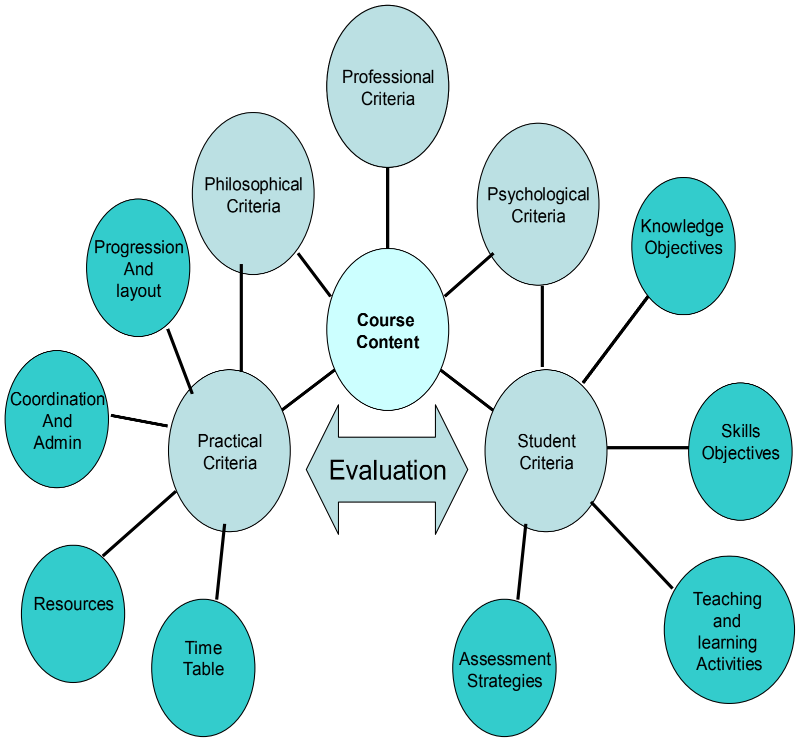

Figure 2: Example of a curriculum planning model

Teaching and learning should take place through a system from the classroom, to department, to institution levels. A coherent system should have an integrated curriculum, teaching and assessment tasks to support learning and to promote students into a higher order learning process (Zoller 1999).

One example of a Curriculum Alignment Project (CAP) developed by Pinkerton (2001) incorporated the CAP to coordinate one semester of activities. CAP's are long-term, multiple approach design and construction projects that provide students with a concrete task to accomplish, rather than an abstract theme to appreciate. Pinkerton found that

> after one cycle of CAPs, student motivation began to change from extrinsic to intrinsic; achievement on objective measures was holding steady; students' abilities to craft and carry out long-term plans for complex projects were improving; and the teacher was learning how to design curriculum that fostered students' need to know.

(Pinkerton 2001)

Inquiry based learning through technology (Edelson *et al.* 1999), or student-driven practicals (Mc Donnell *et al.* forthcoming), are other examples of strategies to promote learning through curriculum design. Jones (1999) has discussed introductory chemistry learning environments that promote the use of design activities which can provide students with opportunities to develop authentic scientific inquiry skills.

> Many of the activities students complete in their coursework are 'school activities', activities conducted only in classroom settings. Seldom are opportunities to carry out more authentic science activities available. However, when asked to design their own experiments and control variables, students must think like scientists. Such authentic experiences are difficult to provide and to monitor in large general chemistry classes. However, multimedia computer based simulated laboratory experiments can give students the opportunity to design and carry out many experiments in chemistry in a short period of time.
>
> (Jones 1999)

Problem based learning (PBL) is a very good example of aligned teaching. In PBL, the aim is to produce graduates who can solve professional problems. The main teaching method is to get the students to solve similar problems, and the assessment is judging how well they have solved them. Most teaching methods could be more effectively aligned than they currently are (Biggs 2002). How we assess should promote learning and drive the learning outcomes.

Assessment models

The role of assessment in accordance with constructive alignment is to achieve the learning outcomes to the best of one's ability. Figure 3 gives just some examples of assessment strategies. These do not include group projects, PBL, and all the other assessment activities used to assess a diverse range of learner types and skills bases. Module descriptors require the assessment weighting and methods to be outlined by the module authors. The competencies envisaged in the learning outcomes should be assessed in the appropriate manner. Clear assessment criteria should be at hand for students to refer to and it should be evident from the assessment criteria 'What they need to know'!

Coppola *et al*. (1997) have restructured their classroom practice and have devised five principles which guide their instructional design to help students develop higher order learning skills. The five principles they have outline are:

1 to give out explicit rules/criteria;
2 use Socratic instruction;
3 create alternative metaphors for learning;
4 use authentic problems to elicit authentic skills;
5 make examinations reflect your goals (constructive alignment).

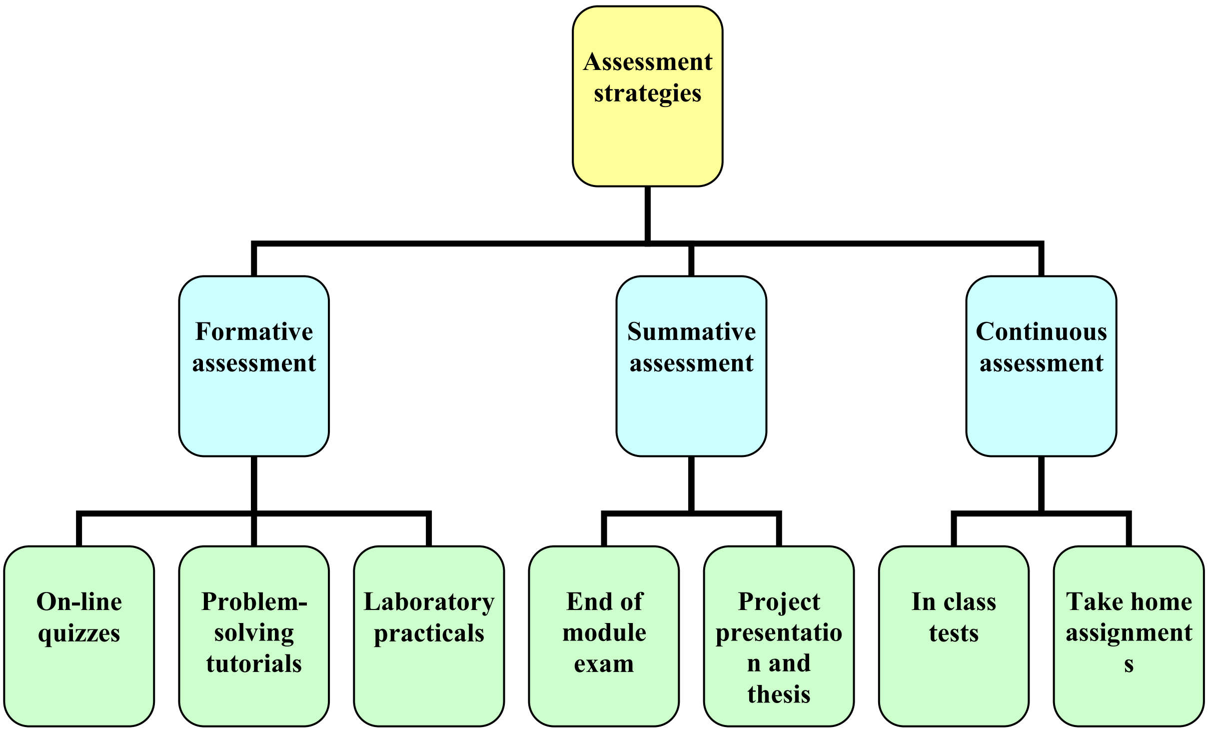

Figure 3: Examples of assessment strategies

Formative assessment in student learning is usually acknowledged, but it is not well understood across higher education. It is argued that there is a need to take account of the epistemology, theories of intellectual and moral development, students stages of intellectual development, and the psychology of giving and receiving feedback. It is noted that formative assessment may be either constructive or inhibitory towards learning (Yorke 2003).

> Assessment should be given serious consideration and reflection and the choice of assessment methods should clearly relate to the learning outcomes. There will rarely be one method of assessment which satisfies all learning outcomes for a module and we would recommend that in devising your assessment strategy, a variety of methods is included.
>
> (Donnelly and Fitmaurice 2005)

Evaluation

> It is therefore important, as part of course design, to develop an evaluation programme which will provide evidence of the degree to which the programme meets its own goals and which also attempts to evaluate the programme from other perspectives.
>
> (Toohey 1999: 197)

Module design and development is a dynamic process and to obtain meaningful information and to improve the module evaluation mechanisms must be put in place. Examples of evaluation mechanisms are questionnaires, interviews and checklists. Kosecoff and Fink (1982) have developed a five step approach to evaluation: (1) formulating questions and standards; (2) selecting a research design; (3) collecting information; (4) analysing information; and (5) reporting information.

Conclusion

The focus of this paper was to answer the initial question asked 'What do I need to know?' from a student's perspective. The answer to this question has been made transparent by the development of coherent curricula through the use of learning outcomes, learning and teaching activities, delivery strategies, assessment strategies and evaluation mechanisms. I hope this brings some clarity to the reader on the importance of planning curricula design for chemical education and some food for thought on how that may be achieved.

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