Improving Performance in a Second Year Chemistry Course: An Evaluation of a Tutorial Scheme on the Learning of Chemistry

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ABSTRACT
Throughput of students is a concern for academic departments especially since it will be the basis of a new funding formula for tertiary institutions. In order to reduce content for increased mastery, and ensure student engagement with chemical concepts, tutorials were introduced for two of the second year chemistry sub-disciplines at UCT in the place of some formal lectures. The impact of this innovation was investigated using questionnaires, interviews and a study of opportunistic data such as examination results. Analysis of the data showed that the overall pass rate increased noticeably as did the number of students achieving high marks. Student, tutor and lecturer feedback lent credence to the belief that the improvement was largely due to the introduction of the tutorial scheme. In addition, some noteworthy differences between the sub-disciplines were identified. Some of these differences were attributed to the lecturer's understanding of his own teaching.

KEYWORDS
Chemical education, curriculum design, improving performance in chemistry, tutorials.

1. Introduction

Student performance in second year university chemistry has long been a concern in South African institutions. This concern has been accentuated by increased student success at the first year level, through interventions such as access courses and tutorial support,[1,2] creating the impression of a gap between first and second year chemistry. Poor success rates at second year also cripple throughput in the degree as a whole, limiting the production of future chemists.

Poor throughput is a source of concern at universities, not only because failure is frustrating for students, but also because it affects income at the institution. The issue of throughput was explored at the University of Cape Town, UCT,[3] and is implicit in the recent implementation of quality assurance by the Higher Education Quality Committee, HEQC.[4] Impending quality assurance by the HEQC will mean that methods will have to be developed to investigate performance of students in courses and how these courses are offered.

This research is located within the paradigm of the scholarship of teaching and learning, where the boundaries between teaching and learning are considered to be artificial.[5] The term 'scholarship' is considered to have a broader meaning, encompassing both teaching and research. In this paper we aim to show how engaging in original research related closely to practice can advance our understanding of success in student learning.

One of the major differences between first and second year chemistry is the division into several sub-disciplines which provide different challenges and hence different performance by students. Little research has been done to investigate student performance in second year chemistry except for work at the University of Witwatersrand (Wits).[6,7] Hence the purpose of this paper is to explore the effect of a tutorial intervention in a second year chemistry course and its impact in two of these sub-disciplines — organic and inorganic chemistry.

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2. Background

2.1. Tutorials in Chemistry

Tutorial schemes are small group teaching strategies that can be organized in several different ways.[8–11] Tutorial sessions have been described as learning situations where 'students work together in groups small enough that everyone can participate in a collective task that has been clearly assigned'.[12] The role of the tutor varies from situation to situation, but the common factor is the active involvement of students in the learning process. By engaging with the material, they would start to grasp the underlying principles allowing them to move from the level of comprehension to synthesis and analysis of information.[13] Clouston and Kleinman noted that when students become active participants in their learning environments, retention of information could reach levels of 90%.[14]

Traditionally tutorials in university have been considered as a form of additional support where students work on problems on their own in a session where they can call for assistance from a senior student or lecturer. In the 1990s there was a move away from this approach and tutorials at the first year level have more commonly been organized in the form of interactive group work.[15] The success of tutorials as a form of group work is attributed to their cooperative nature and hence the enhancement of student ability to learn in a social way.[16] Brodie and Pournara identify several types of group work, each informed by an underlying view of teaching and learning, type of task and the role of the tutor. In this study the conception of the tutorials was based on a sociocultural view of learning where the tutor is regarded as a more capable peer who aims to reach a shared meaning of concepts with the students. The mediation role played by the tutor is far more proactive than the traditional role conceived of in the past.[16]

Much of the success in first year chemistry has been attributed to work done in tutorials[1,2,17] and there are signs that tutorial approaches have been successful at the second year chemistry level.[7,18]

2.2. Teaching Second Year Chemistry

A holistic investigation of the gap between first (Y1) and second (Y2) year chemistry was carried out by Green[19] at the University of Witwatersrand. Green uncovered aspects of the gap related to the interface between first and second year chemistry as well as the progression through second year. Several examples are given below.

- Students on both sides of the interface were overloaded in terms of content. This was exacerbated at the second year level.
- There was insufficient emphasis on important prerequisite concepts in Y1 and lack of active transfer of these to Y2.
- Concepts were delivered at a much deeper level in Y2 compared with Y1 and new second year students were unprepared for the volume, pace and variety of work at that level.
- Identification of different knowledge structures for the separate sections of the course, such as organic and physical chemistry suggested pedagogical interventions that may facilitate understanding.

Green made a number of recommendations as a result of her research. Those relevant to the current study are shown below.

- Reduce the content for increased mastery.
- Identify key concepts underlying the discipline and design activities to ensure student engagement with these topics.

Green's recommendations point to the need for targeted intervention. These interventions need to be made with a thorough understanding of teaching and learning at the tertiary level. By the time Green conducted her study in the late 1990s, a tutorial scheme was in operation at the second year level at Wits, largely as a result of research carried out by Bradley *et al.*[18] They had found that the course was overloaded and recommended that tutorial activities be implemented to address the content intensive delivery of the course.

2.3. The Role of the Subject Matter of the Discipline

The discussion above has focused on the academic experience of students but another essential factor in student success is the nature of the subject to be studied. Erduran and Scerri noted that students in advanced chemistry classes experience difficulties with many topics in chemistry.[20] They provide an insight into how an understanding of the structure of chemical knowledge could improve teaching and learning in the subject.

Green and Rollnick analysed the content of the sub-disciplines in the second year chemistry course and showed that they are different in nature and concepts.[6] They proposed the idea of linear versus non-linear development of concepts and knowledge construction. In linear modules, comprehension of basic concepts would be essential in order to build a secure knowledge base. Organic chemistry is an example of a linear sub-discipline. One of the fundamental principles is the interaction of nucleophiles (electron-rich centres) and electrophiles (electron-deficient centres) to predict the outcome of a particular reaction. Movement of electrons during the reaction is indicated by the use of curly arrows. Students who are not able to apply these concepts would find organic chemistry very difficult.

Organic chemistry involves symbols, pattern recognition, multiple representation and application of principles. Different representations are used interchangeably and students who are unable to recognize these formats will easily become confused. Johnstone makes the point that understanding chemistry involves working at three levels, the macroscopic, microscopic and symbolic.[21] Reactions in organic chemistry are presented in symbolic form while the interpretation of the reaction mechanisms is interpreted at the macro- and microscopic levels. New learners to a discipline would have difficulties in operating at all three levels simultaneously.

Pungente and Badger argue that the teaching of organic chemistry should take students beyond the simple cognitive levels of knowledge and comprehension.[13] They use a mechanistic approach in their teaching in which they stress the connections to the fundamental issues. Students start to see the appearance of the underlying principles throughout their study of organic chemistry and begin to understand the complex reactions which can seem confusing for the beginner. Performance in organic chemistry will reflect the students' ability to operate at the three levels described as well as being able to grasp the fundamental principles outlined above. Thus rote learning will not yield the desired outcomes for students i.e. passing the course.

On the other hand, sub-disciplines which are non-linear are less dependent on a single thread which links the concepts. The inorganic chemistry sub-discipline is non-linear in that a number of topics such as molecular orbital theory, main group chemistry, transition metal chemistry, are introduced in a more or less independent manner. A student who fails to acquire a deep understanding of the concept of molecular orbital energy diagrams would nevertheless be able to describe the chemistry of the main group elements. Interestingly, the chemical education literature is relatively silent on problems associated with the learning of inorganic chemistry.

Organic chemistry has been described as a 'washout' course with a 'bad reputation of mythic proportions'.[22] A marked improvement in student performance in organic chemistry was observed using an intervention by Huddle.[7] She introduced a poster session in the second year organic chemistry course at Wits to engage students with one of the most important aspects of learning organic chemistry, namely the use of curly arrows to show the movement of electrons during the course of a reaction. This intervention led to a dramatic improvement in the results for this module in the second year course.

3. Aim of this Study

The overall aim of the research was to examine the effect on student performance of reducing the content for increased mastery in a targeted second year course. In particular:

- What was the impact of the introduction of a weekly tutorial scheme?
- What differences, if any, were there between student learning in the sub-disciplines in the course?
- What was the impact of the tutorial scheme over time?

4. Sample and Context

The students who formed part of this study were a mixture of science and chemical engineering students, all in their second year. As first year courses at the University of Cape Town offer tutorial support on a weekly basis, these students would have been accustomed to receiving such support in their first year. However, at the time of the study, tutorials were held only on an occasional basis during the second year.

As in other South African institutions, the second year chemistry programme at UCT is made up of several components, called courses. There are two compulsory second year chemistry courses which are prerequisites for students wishing to specialize in chemistry. One is run in the first semester and focuses on physical chemistry and spectroscopy while the other is run in the second semester where the focus is on organic and inorganic chemistry. The organic and inorganic course is subdivided into separate sections, with a slight bias towards organic chemistry in terms of course content.

5. Research Design

This study is an evaluation of the impact of the introduction of a weekly tutorial scheme in a second year chemistry course. On the basis of the work done by Green[19] the staff in the department were persuaded that students would benefit from fewer formal lectures and some of the lectures should be replaced by tutorial sessions. Hence in 2003 one lecture per week was replaced by a tutorial session, resulting in a reduction in course content for both topics in the second semester course. In addition the occasional tutorials already in place were also retained.

Two questionnaires were administered to students just before the final examination. The first was designed to gauge their attitudes to the introduction of the tutorial scheme[23] and the second to gather feedback on various aspects of the course including the introduction of the tutorial scheme. The first questionnaire[23] yielded quantitative scores on a scale of 1 to 7, with 7 representing the most positive attitude, while the second questionnaire yielded purely qualitative data.

Interviews were conducted with tutors and lecturers and marks for the final examination were collected for the period 2000–2004. Other opportunistic data was also gathered such as examination papers and tutorial exercises. These were subjected to content analysis by experts not involved in the course.

6. Implementation of the Tutorial Scheme

Two particular challenges related to organizing tutorials at the second year level are the limited personnel available with the prerequisite understanding and the shortage of resources ready made for teaching at this level. It is often assumed that students at this level should be able to learn on their own. Taagepera and Noori suggested that where students' knowledge is algorithmic rather than grounded in basic principles, they will have difficulty in solving problems or retaining knowledge.[24] Lecturers should reduce their course content and spend more time in helping students to 'make the connections'. Huddle suggested that students require comprehension and constant practice of problems to be successful at organic chemistry.[7] It was felt that the tutorial sessions, which were compulsory, would force students to practise their organic chemistry. By engaging with the material, they would start to see the underlying principles allowing them to move from the level of comprehension to synthesis and analysis of information.

Because of our belief that learning at all levels is a social process,[16,25] students need to learn the value of group engagement at an early level. Given the shortage of qualified tutors (we were limited to a researcher and postgraduate students in chemistry), we decided to form 6 groups of about 21 students per group, each under the guidance of a tutor. In these groups, students typically worked in smaller groups of 3–4, working through pre assigned tasks with the assistance of a tutor who would occasionally call the entire class together to solve common problems. Tutors were postgraduate students engaged in research in either organic or inorganic chemistry. The tutorials were held once a week in place of the scheduled lecture. Problem sets were distributed several days before the scheduled tutorial. Each week the lecturer held a meeting with the tutors to discuss the concepts in the tutorial and the marking of selected problems. Tutors were issued with a set of solutions. In order to increase the motivation of the students, marks for tutorials contributed to the students overall mark for the course. Solutions were placed on the notice board after the tutorial and were displayed for several weeks before being removed. They were not distributed to students as experience with first year students had shown that issuing students with solutions led to passive study habits.

7. The Impact of the Introduction of a Weekly Tutorial Scheme

The impact of the tutorial scheme is presented from the perspectives of all the role players.

7.1. Students' Perspectives

The global average for the questionnaire probing attitudes to the tutorial scheme was 5.4 on a scale of 1–7 where 7 was the most positive attitude and 1 was the least positive. In particular students felt that chemistry tutorials were a good way of learning chemistry. Thus:

> 'Tutorials give me a chance to ask about things I have not understood in lectures.'

and

> 'I get a chance to think more about what I have done in lectures.'

Preparing in advance for chemistry tutorials is important as it meant that:

> 'I understand better what I have to do.'

A second questionnaire was administered to probe specific aspects of tutorials. Students provided positive feedback about the tutorials with many suggestions for improvement for subsequent years.

> 'I found the tutorials extremely beneficial. They provided useful practice for the course material. I had no problems with them. Only I would have liked to have had them for CEM207F *(the second year chemistry physical chemistry and spectroscopy course)* as well.'

> 'Tutorials are very helpful. I feel on top of my work because I have to work every week.'

Quote from student (immediately after having written the examination):

> 'I am a CEM208S student in 2003. I just want to say how important tutorials were for the course this year. I am repeating the course and I found it very easy this year with all the help of practising the tutorials for each section covered in class every week. I think the whole idea of changing the way the course used to be was very good. The tutorials and the class notes were so helpful I did not even need to use the textbook for the exams. I think the system should continue and the pass rate of CEM208S will even go higher. Tutorials also helped students who are from the first year course to practice on their own and not get lost on what is happening in class as the rate is not the same *(as it was last year)*. And now I don't even have doubts I know I PASSED the exam. Tutorials were really helpful to us students doing CEM208S.'

The student passed the examination and the course.

7.2. Lecturers' Perspectives

The lecturers were also gratified with the innovation. They said:

> 'This was the best arrow pushing class, they committed less chemical heresy. The students have done very well. The provisional pass

rate is about 85% with 24 (19.6%) students getting first class. As far as organic chemistry is concerned, the students generally did very well. We should note that this year the material covered is less compared to previous years.' (Lecturer Org)

'My impression is that the tutorial scheme helped. Particularly with Molecular Orbital theory for bonding in diatomic molecules, which has been poorly understood in the past. I suggest we do the tutorial scheme again next year.' (Lecturer Inorg)

An interview with the main lecturer in organic chemistry provided a window into his philosophy about teaching. He identified what he referred to as reactivity principles as being fundamental to the understanding of organic reactions. His method of formulation is more overt than can generally be found in textbooks, and integrates his knowledge of students, context and pedagogical principles to make this knowledge accessible to the students. He believed that:

'Learning organic chemistry is like learning how to drive a car, or learning how to sing, you got to rehearse, if it's a game of soccer or organic chemistry, you got to train. Even when you know how to play soccer, how to kick the ball, you got to train and train until it becomes a second nature.... When we describe organic chemical activity, we talk about, the types of reactions, for example, substitution, addition, elimination, three types of reactions. When it comes to reagents that you have two types of reagent, for polar reactions, we use nucleophiles and the corresponding electrophiles.... Whenever we are trying to explain organic chemical reactivity, they don't need to look beyond two types of effects, the electronic effect and the steric effect so the thing is this, to really assure them *(the students)* that although it appears as if they had a large body of information and knowledge and that, what they going to have is even more new information, that is **absolutely not true** *(emphasized)* but it's the same thing they doing, but expressed in different ways and forms, different molecules and structures....'

The idea of concentrating on the fundamental principles and training to become proficient at drawing reaction mechanisms was emphasized throughout the course and was the basis of the type of tasks which formed the problems sheets for the tutorials.

Although the lecturer in inorganic chemistry commented favourably on the tutorial scheme, he was less involved in the tutorials than the organic chemistry lecturers. The main lecturer for the organic module bought into the scheme, participating actively and making changes to his lectures as feedback was provided from the tutor/researcher. He commented:

'As course convenor and lecturer for CEM208S, I was responsible for setting all formal tutorial problems for the organic chemistry component of this course. Each time I set questions, the researcher, who was a tutor, who would go out of her way to go through the tutorial questions and provide me with feedback and constructive criticism before the students attempted the questions. I found the feedback to be extremely useful in improving my tutorial questions and pitching them at an appropriate level for the students.' (Lecturer Org via e-mail).

Although members of academic staff generally agree that there is a problem to be solved, not all are willing to make the investment in time and effort required to study this problem in depth. The inorganic chemistry lecturer, though in favour of the tutorial scheme, saw it largely as a supplementary add on to the course rather than an integral part of the teaching operation. In a meeting with the tutors, he commented that tutorials were an opportunity to challenge students.

7.3. Tutors' Perspectives

In general there was also a good response from the tutors to the introduction of the tutorial scheme. Interviews with tutors revealed that:

'Tutorials encourage students to work together and go through their work. By the third organic tutorial there was a marked improvement. Tutorials are a relaxed environment compared to lectures; students are able to ask questions more readily.'

In the case of the organic chemistry all tutorial sheets were provided well in advance together with detailed solutions. A weekly meeting was held with the tutors to discuss the questions and their purpose. The effort made by the students was apparent in the tutorials. An interview with two of the tutors revealed that the lecturer in organic chemistry had insight into student difficulties:

'And also ... it seems when he does his lectures, he sort of knows where the students are having weaknesses or problems, and when he comes to the tutors he tries to fill in that particular gap, so much so that the lectures and the tutorials, really complete the whole story, really seals the whole thing, so that the students understand what is going on, and he *(the lecturer)* also asks for feedback, to really make sure that if there is a problem in the tutorial he can actually go back in the lecture and try to address those particular issues, so it's a kind of complete cycle.'

On the other hand there was evidence that the inorganic tutorials were less well prepared. Information-gathering e-mails solicited from the tutors revealed that the first tutorial in particular suffered from various problems. All commented that the questions were too vague to enable students to give focused answers and the solutions supplied to the tutors required them to do extensive research to find answers and consequently it was difficult to grade the students' work in a consistent way. Minutes of an evaluation meeting held at the end of the semester revealed that the issues identified in the initial inorganic tutorials improved but still remained a problem by the end of the course. Given that there were only three tutorials it was difficult for the staff to create a culture in the tutorials in the same way as had happened in the organic chemistry.

8. Student Performance

The evidence cited above drew on reactions to the innovation. It is important to see if these translated into improved performance on the part of the students. The performance of the students in the 2003 examination needs to be examined in the context of previous performance over a number of years. Figure 1 shows the results for Y2 students over a period of 5 years.

There was a small increase in the pass rate between 2001 and 2002 with a larger increase in the pass rate for 2003 and 2004. An examination of the final marks provides more insight into student performance. Not only did the pass rate improve in

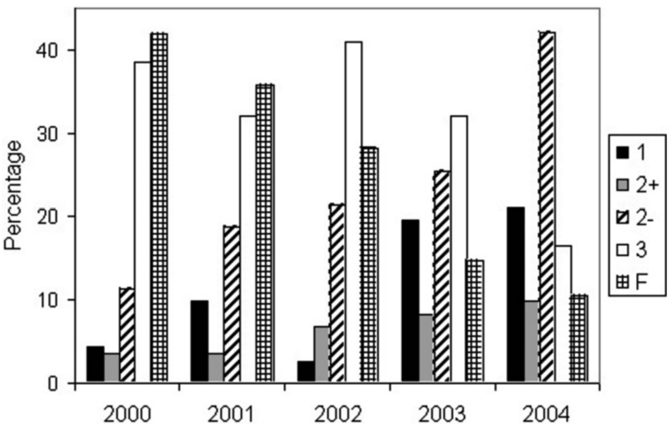

Figure 1 Y2 Final Marks 2000–2004.

2003, but the proportion of students achieving higher marks also increased. For example, the percentage of students achieving a first class (1 in legend above) in 2003 increased dramatically from all previous years. The findings show that overall the introduction of tutorials appeared to have a positive effect. The effect on student performance in 2003 was certainly more dramatic in the case of organic chemistry but both students and teaching staff in both sub-disciplines regarded the intervention as valuable and the scheme was continued with some modification in 2004.

9. Differences in Learning in the Two Sub-disciplines

There were differences in experiences between the organic and inorganic chemistry. Although there were 28 organic chemistry lectures and 20 inorganic chemistry lectures in 2003, there were only three inorganic chemistry tutorials compared with six in organic chemistry. Student performance in organic chemistry dropped substantially in 2002 and the course designers were aware of similar problems with organic chemistry at other institutions as well as the general characterizations of difficulties in organic chemistry cited above. A search of the literature failed to uncover similar reported problems in inorganic chemistry. Figure 2 shows the percentage of students passing the different sections of the paper.

In 2003, for the first time in four years, the percentage pass for the organic chemistry section of paper was higher than for inorganic chemistry. The pass rate for inorganic chemistry showed a small improvement from 2001 to 2002, but stayed approximately the same between 2002 and 2003. Student performance in organic chemistry had been low from 2000–2001, but dropped dramatically even from this level in 2002. This drop was ascribed to a change in lecturing staff and hence teaching style during 2002, but the improvement in 2003 clearly outstrips any pass rates obtained since 2000. The trend of organic chemistry marks being lower than inorganic marks is not unusual and was also observed by Huddle at Wits University.[7]

The differences observed between the two sub-disciplines in 2003 reveal important ingredients of a successful tutorial operation. The differences between the two interventions were as follows:

- There were twice as many tutorials in organic chemistry.
- Tutorials were integrated into the teaching of the organic chemistry, whereas in the inorganic chemistry, they were seen as add-on support.
- The lecturer in organic chemistry capitalized on important structural issues related to knowledge of the nature of the sub-discipline.
- The involvement of the lecturer.

As mentioned above, a decision was taken to provide more tutorials for the organic chemistry as students had been under performing in this area in previous years. However, the provision of only three tutorials for the inorganic chemistry made it very difficult for the tutors to allow the students to gain an idea of the nature of knowledge in the sub-discipline. On the other hand, the six organic chemistry tutorials allowed sufficient time to establish a culture of participation and appropriation of basic concepts.

In the inorganic chemistry course, it was clear that the tutorial sessions in 2003 were not integrally related to the lectures – students were unsure of what was required by the questions, as were tutors, and solutions were vague. There is also no evidence that the lecturer made use of information gathered during tutorials on difficulties experienced by students during the lectures. Conversely in the organic chemistry section, the

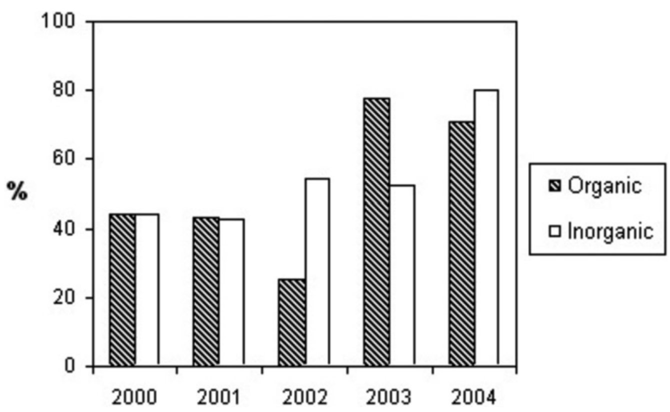

Figure 2 Percentage pass for Y2 sub-disciplines.

lecturer saw the tutorials as an essential part of the course and used feedback from the tutors in his lectures. He also used the experience from the tutorials to inform the examination paper at the end of the course. Nevertheless the inorganic chemistry lecturer did value the tutorials and felt that they provided good backup for his teaching. He made some changes for the 2004 tutorial sessions which led to an improvement in performance in the inorganic chemistry sub-discipline in 2004. These are discussed below.

It would be easy to ascribe the improvement in organic chemistry performance in 2003 simply to the introduction of the tutorial scheme but this intervention alone cannot explain the gains made. Much of the success needs to be attributed the personal involvement and enthusiasm of the lecturer in organic chemistry. He integrated knowledge of students, a knowledge of the discipline and knowledge of the teaching context.[26] In all these aspects, the lecturer displayed awareness as well as an ability to integrate them into his teaching. He displayed a tacit knowledge of pedagogical principles by the way he synthesized the tutorial sessions with his lecturing, he displayed a knowledge of the students by showing his awareness of their difficulties and also used contextual factors to his advantage.

What is most interesting is his transformation of his content knowledge and his understanding of the structure of the sub-discipline. Although he did not explicitly describe the difference in structure between organic and inorganic chemistry, it is clear that he recognizes that there are basic underlying concepts to be mastered without which the student cannot proceed with the material. A realization of this fact allows for a dramatic improvement in performance in the sub-discipline. In her intervention in organic chemistry Huddle noted that:[7]

> 'Over the years I, together with a colleague, have kept abreast of the literature and introduced various techniques into the Organic II module in an attempt to increase student participation and achievement. Never have I been so upbeat about the effect of a change as I have been after the introduction of the poster session. Colleagues in the department commented on the improved attitude of the students to the ChemII Organic module.'

10. The Impact of the Tutorial Scheme over Time

Since overall student performance increased dramatically in 2003, the tutorial scheme was retained for 2004. Figure 2 shows that the marks for the organic chemistry section of the course dropped slightly but were still at a much higher level than in 2002, before the introduction of the tutorial scheme. In the organic chemistry examinations, tutorial questions were not directly repeated, but as the lecturer said in the interview:

'I like to model them *(the exam questions)* on the tutorial problems; I like to structure them *(the tutorial questions)* with the exam in mind.'

On the other hand the inorganic marks showed a large increase in 2004. Content analysis of the inorganic tutorials and examination papers showed that there were several changes to the inorganic course in 2004. Firstly, the number of tutorials was increased from 3 to 4. In addition, there was more widespread coverage of content over the four tutorials. In 2003 the tutorials dealt mainly with main group chemistry, as did the examination while in 2004, more tutorial time was devoted to molecular orbital theory and transition metal complexes, rather than main group chemistry which tends to be more descriptive in nature. Interestingly, the 2003 examination contained one question extracted directly from the tutorials (20% of the total marks), while in 2004 no less than three questions similar to those in tutorials were included in the final examination (60% of the marks). However, it should be noted that the 2004 examination paper was at a higher cognitive level than the 2003 paper and both the 2003 and 2004 papers were at higher cognitive level than the 2002 paper. Despite this increase in difficulty, the students performed as well or better. The marks in organic chemistry were at a similar level to 2003, but more than matched by the improvement in inorganic chemistry.

11. Conclusion

What has emerged from the study is that the introduction of the tutorial scheme has had a positive effect on students' experience of the course as well as their performance. Initially in 2003, the effect was more dramatic for the organic chemistry module where the tutorials were integrated into the course and student performance had been very poor the previous year. The lecturer in organic chemistry used the tutorial problems as a starting point for the questions in the examination. The increase in the number of tutorials in inorganic chemistry in 2004, as well as a closer correspondence between the tutorial problems and the examination questions led to an improvement in the performance of the students in this sub-discipline and a slight improvement in the overall pass rate for the course.

At the beginning of this paper we referred to the centrality of the scholarship of teaching. Although not trained teachers, Boyer considers teaching to be a central part of the scholarship of academics.[5] He says,

'Further, good teaching means that faculty, as scholars, are also learners. All too often, teachers transmit information that students are expected to memorize and then, perhaps, recall. While well-prepared lectures surely have a place, teaching, at its best, means not only transmitting knowledge, but transforming and extending it as well. Through reading, through classroom discussion, and surely through comments and questions posed by students, professors themselves will be pushed in creative new directions.' (page 24).

This study has shown how important tacit knowledge of teaching is to improving teaching even at the tertiary level. Structural changes to a course such as the introduction of a tutorial scheme can have positive effects but a coordinated approach and integration into teaching is vital to allow the intervention to have maximum impact. University academics are not generally trained to teach; they are subject matter specialists and need some pointers about how to transform their knowledge for teaching.

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