

TEACHING FOR QUALITY LEARNING IN CHEMISTRY

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Abstract: In Portugal, the number of students in Higher Education increased from 80 000 in 1975 to 381 000 in 2000 (a change from 11% to 53% in the age group 18-22), meaning a major change in the diversity of student population with consequences well known and studied in other countries. The teaching of Chemistry at the University of Aveiro, for the first year students of Science and Engineering, has been subjected to continuous attention to implement quality and student centred approaches. The work devoted to excellence and deep learning by several authors has been carefully followed and considered. This communication reports research work on Chemistry teaching, associated with those developments for first year students. The work included the design of strategies and the adoption of teaching and learning activities exploring ways to stimulate active learning by improving the quality of classroom interactions. In addition to regular lectures, large classes' teaching based on students-generated questions was explored. In order to improve students' motivation and stimulate their curiosity, conference-lectures were adopted to deal with selected topics of wide scientific, technological and social interest. Quantitative analysis and discussion of selected case studies, together with the organization of laboratory classes based on selected enquiry-based experiments, planned and executed by students, stimulated deep learning processes. A sample of 32 students was followed in the academic year of 2000/01 and the results obtained are here discussed in comparison with those of a sample of 100 students followed in 2001/02. Particular attention was paid to the quality of classroom interactions, the use of questions by students and their views about the course design.

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1. INTRODUCTION: QUALITY LEARNING AND THE NATURE OF ENGAGEMENT

This paper is underwritten by two broad assumptions, that:

1. To increase interaction between the learner, teacher and learning task is to improve the quality of the learning experience, and that
2. One indicator of this interaction is the number and level of student-generated questions within the learning context.

We deal with these two assumptions first before describing work within undergraduate Chemistry aimed at enhancing the quality of learners' experiences. Our principal interest lies in raising the quality of teacher-student interactions in university classrooms and – in this case – university laboratories. To achieve this, our research has been designed to develop innovations in course design and planning procedures to incorporate a broad range of learning methods and, more specifically, to encourage and explore the use of 'quality questions' by undergraduate chemistry students. We have reported earlier elements of this work in Pedrosa de Jesus et al (2003).

To explore the first assumption above is to consider 'quality learning', which Biggs (1982, p174) describes as:

... the development of students' intellectual and imaginative powers; their understanding and judgement; their problem-solving skills; their ability to communicate; their ability to see relationships within what they have learned and to perceive their field of study in a broader perspective, to stimulate an enquiring, analytical and creative approach; encouraging independent judgement and critical self-awareness (our emphasis).

The key verbs in that description are 'to develop', 'to stimulate' and 'to encourage' students. While these actions do lie within the learner's ambit, they are also those that relate to the teacher: it is part of the teacher's responsibility, we believe, to develop, to stimulate and to encourage. Biggs' picture of learning dovetails neatly with what has been called 'engagement in learning'. In Watts & Alsop (2000), for example, a model of 'engagement' is proposed which is then explored through the eyes of

learners, their first-hand experience of what it means to be fully engaged in a learning activity. A learner engaged with a particular topic, it is argued, is someone who is seen to be engrossed in, and actively challenged by what is involved - connected to and immersed in a particular topic for a significant period of time. During that time, the topic is thought to be intriguing, stimulating and even entertaining. The learner acts independently, is enquiring, explores relationships, solves problems creatively, is critical and aware. Clearly, to arrive at such a state of being is not to be underestimated. Along these lines, then, we suggest that 'Quality learning can be defined as changes in learners' actions and interactions that take place as a result of being fully engaged in a quality learning experience'.

To be dis-engaged is, of course, the converse of the above. Such a learner becomes uncommitted, disinterested, uninvolved and withdraws from the general sphere within which this learning might otherwise have taken place. There are likely to be many reasons for disengagement and some of these attached to the learner, some to the environment, the curriculum, the task and the approach to teaching. Disengagement with school science, for example, has been discussed by, among others, Baudoin *et al* (1999), Stark & Gray (1999), Millar & Osborne (1999) and Osborne & Collins (2001).

Our purpose in this paper is to discuss means by which engagement can be enhanced rather than diminished. Biggs (1999, p73) suggests that to *increase* quality in learning is to increase the interaction between the learner, teacher and learning task which, in turn, he sees to trade upon

1. A learner's well-structured knowledge base
2. An appropriate motivational context
3. Learner activity, so that active learning is better than inactive, or passive, learning.

One means of achieving this, we believe, is through the stimulation, encouragement and development of student-generated questions during the process of learning.

2. STUDENT-GENERATED QUESTIONS

In this paper we are concerned with the questions asked by learners, in this case university chemistry undergraduates as they embark upon a search for understanding in their studies. Our work is concerned exclusively with those questions asked by learners, and not with the routine asking of questions by teachers. In everyday life, questions take on a multitude of forms and purposes. Ordinarily, to question is to ponder, seek answers to a puzzle or a problem, to encounter a perplexity that requires resolution. In this sense, we follow a route suggesting that the questions asked by learners are indicative of their need for some degree of interaction with both teachers and other students within sessions, for understanding within the domains in which they are working and studying and for some resolutions in their thinking. Student-generated questions, therefore, are an important element in the teaching/ learning process, for at least the following reasons:

- i) Questions can lead to improvement of understanding and retention of what a student encounters
- ii) Questions can drive classroom learning and are highly effective in increasing student interest, enthusiasm and engagement
- iii) Learners' questions can be diagnostic of their understanding. Even when questions are poorly formed they indicate 'an active, interrogative attitude that not only seeks appropriate information and opinion but also allows some determination of the worth of what is read or heard' (Watts & Pedrosa de Jesus, 2001).

A growing number of educators now emphasise the importance of students' questions in both teaching and learning for understanding, and the number of investigations looking for ways to stimulate students to generate questions is growing (Zoller, 1987, 1984; Commeyras, 1995; Rosenshine *et al*, 1996; Maskill & Pedrosa de Jesus, 1997a; Watts *et al*, 1997; Marbach-Ad & Sokolove, 2000). Studies at different educational levels and contexts generally indicate that learners avoid asking questions (Susskind, 1969, 1979; Dillon, 1988; Pedrosa de Jesus, 1991). However, there is also

strong evidence that if ‘good’ conditions are created (appropriate conditions conducive to the generation and asking of student questions) then students are willing to ask meaningful questions (Pedrosa de Jesus & Maskill, 1993; Maskill & Pedrosa de Jesus, 1997b). In general, learners will ask questions where they have high levels of self-confidence and self-esteem within the learning context, and where their questions are seen (Watts *et al*, 1997) to be valued. In some cases, asking even poorly formed and tentative questions can indicate an active, interrogative attitude that not only seeks appropriate information and opinion but also allows some determination of the worth of what is read or heard.

Our interest in this paper lies with the second of the propositions above, that student-generated questions can drive classroom learning and are highly effective in increasing student interest, enthusiasm and engagement. Working within one university department of Chemistry in Portugal, the staff of the department has been encouraged by the flow of student questions to re-shape their approaches to teaching and learning and, in four distinctive ways, have ‘tuned’ their curriculum provision to respond to these questions. This tuning is described below.

3. TUNING UNDERGRADUATE CHEMISTRY

In Portugal, the number of students in higher education has increased from 80,000 in 1975 to 381,000 in 2000 (a change from 11% to 53% in the age group 18-22), meaning a major change in the diversity of student population with consequences well known and studied in other countries. The structure of teaching pattern used at University of Aveiro provides lectures for some 120 students at a time, with audiences comprised of students from a range of courses related to mainstream foundation chemistry but who would later specialise for their final degrees. More focussed teaching takes place in seminar-tutorial sessions where groups of 32 students cover issues with the same lecturer as in the large classroom. These seminar-tutorial sessions are used for clarifying and illustrating, in dry-lab situations, the concepts previously explained in the large classroom. Laboratory sessions are run for groups of 15 students,

and are supervised by teaching assistants and technical staff. In this way, the teaching is undertaken by a number of academic staff, who work hard to ensure that the programme is coherent and well coordinated, to diminish any fragmentation and to create good interpersonal interactions with students. With innovation in mind, the teaching of chemistry at the University of Aveiro, particularly for the first year students of Science and Engineering, has been subjected to continuous attention – tuning - to implement quality and student centred approaches.

What Biggs (1999) calls ‘constructive alignment’, we have called ‘tuning’. This is the deceptively simple idea of aligning intended learning outcomes with teaching and learning activities, with both these in turn being aligned with assessment procedures. The course at Aveiro has been tuned, or aligned, through consecutive course editions towards both the requirements of the curriculum and the satisfaction and involvement of the students, within which student-generated-questions play an important role. This activity of tuning is not so much a result of a once-for-all modification, but a relatively constant concern and evolution that requires almost permanent consideration of students’ questions and of student-teacher and student-student interactions. As a result, the course matter has undergone two levels of tuning: ‘fine’ tuning and ‘coarse’ tuning.

Fine-tuning has involved small shifts in practice, protocol, subject emphasis or minor subject diversions suggested to students or by students. Three examples will illustrate this kind of tuning. First, as part of the background to the programme, course objectives for Chemistry at the university are set out in a Guide for Students and in a Students Manual. These are designed to encourage student participation so that this involvement is at the heart of the learning process. Second, a major precondition for the success of this work is that students feel free to ask questions of the teacher and are encouraged to do so at any time in the classroom. That is, the atmosphere surrounding the student must provide plenty of stimulus and encouragement for development. The students in this course are invited to raise both oral and written questions on and around the subject matter and address them to the teacher, with several routes provided for them to do so, as described below. A key principle is that, to enhance students’ willingness to interact in the classroom, the course matter should not divert into deep or long theoretical arguments and explanations that act to reduce the student to the role of

simple spectator in the classroom. This is always a distinct possibility in a first year university Chemistry course – to wholly ‘baffle the learner with science’. Third, the teacher must respond to questions, and his/ her responses are given in two ways, through a dedicated computer software system used to provide the students, with answers, explanations, advice and with suggestions for further reading, with the encouragement to raise follow-up questions. While responses are made to specific student questions, these are then available to all who log into the system. Provision is also made within the lecture system to tackle both general and particular student questions, so that teachers’ responses are made available to the whole student group on the programme. These innovations are aimed at improving the students’ learning process and helping them towards constructive and engaged learning.

Coarse-tuning has meant turning these ‘minor’ moves into a more structured reality, by creating and adopting strategies for teaching and learning that explore ways to stimulate active learning by improving the quality of classroom interactions. This has entailed the use of teaching based on students-generated questions in small group work tutorials in addition to regular lectures and large class sessions. In order to improve students’ motivation and stimulate their curiosity, ‘conference-lectures’ were adopted to deal with selected topics of wide scientific, technological and social interest. Quantitative analysis and discussion of selected case studies, together with the organization of laboratory classes based on selected enquiry-based experiments, planned and executed by students, have been further used to stimulate engagement. These coarse developments have taken the following five forms:

(i) ‘QQ lectures’

As mentioned above, student-generated questions are highly effective in increasing student interest, enthusiasm and engagement and can drive classroom learning. Capitalizing on this, the department introduced, at the end of each topic, one additional lecture based on student-generated questions on a related, yet not previously planned, issue. The acronym ‘QQ’ stands for ‘Questões em Química’, the running title for much of this initiative at Aveiro. These are large classroom lectures, based on questions students have presented to the lecturer in the week preceding the lecture. In

framing a response to these questions, the lecturer selects a broad case study, usually from within chemistry to exemplify the topic and address students concerns. The students are advised to read further on the selected topic from chapters in the recommended textbook, in order to increase the number and improve the quality of their questions. Some examples of topics selected for the 'QQ-lectures', during the 2nd semester have been Acid Rain, Fuel Cells, The Ozone Layer and Conducting Polymers.

(ii) Conference-lectures

These have been entirely voluntary lectures on selected chemistry topics of wide scientific, technological and social interest intended to stimulate and enhance student's curiosity in chemistry. There were three such conference-lectures organised in the period February to May, on 'Batteries and Fuel Cells'; 'The Origin of the Chemical Elements'; and 'Oscillating Reactions'. These additional lectures 'on demand', not included in the regular lecture timetable, provide a way to estimate the degree of students' enthusiasm and interest in chemistry. These lectures have each drawn audiences of about 50 students from the cohort of 200 in Semester 2. Lecture notes were issued ahead of the lecture to ease access to some potentially complex issues in chemistry.

(iii) Seminar-tutorial sessions

While the seminar-tutorial sessions were considered natural extensions of the large classroom lectures, they provided better opportunities for interpersonal interactions with the students, since the classroom in these sessions did not exceed 32 students. Instead of simply providing the students with lists of dry-lab exercises, each of these tutorial sessions presented a particular case study related to the subject matter previously lectured in the large classroom. These case studies have aimed at providing the student with opportunities to learn the process of 'doing science', of investigating the principles of chemistry and, occasionally, of discussing current social and economic applications. In contrast to formula-based exercises that address specific dry-lab situations - and where the format relies principally upon finding a particular formula and substituting in the provided data chosen to produce 'neat and tidy' results - these

tutorial sessions focussed on more general situations. They have required students to: (a) analyse the case study in hand, (b) propose a structured line of thought, (c) proceed in finding and selecting the data provided in a book of data, (d) discuss the results and, eventually, (e) explore practical applications in day-to-day situations.

Some examples of case studies used in the seminar-tutorial sessions (2nd semester 2001/2002) have been:

Acids and Basis – Consider an aqueous solution of a Bronsted-Lowry weak acid. Present and discuss the approximations that may be used for evaluation of the solution pH. Provide concrete examples that illustrate those approximations.

Redox Reactions I – Consider a metal that reacts with an acidic solution and one that does not. Present and discuss the conditions for each case. Provide examples of each.

Redox Reactions II – Consider a metal with at least two positive oxidation states. Present and discuss the conditions for the metal to undergo comproportionation or disproportionation. Provide examples of each. Calculate the extent of the reaction in each case.

Hydrocarbons – Consider the normal boiling points of hydrocarbons. Investigate possible correlations with molecular or structural features. Plot and discuss the encountered correlations. Do they originate any practical applications? Discuss them.

In these seminar-tutorial sessions, students are encouraged to interact with other students and/or with the teacher in a relaxed atmosphere. In turn, the teacher's intervention in the classroom has been to orient and encourage students to ask questions, recognize difficulties that arise and find adequate and efficient strategies to meet these.

(iv) Practical laboratory sessions

In a typical university Chemistry laboratory manual, little is left to student initiative or circumstance: laboratory work and procedures are generally carefully listed and planned. Frequently the student is asked simply to fill in the blank spaces left in a

previously pre-determined and structured report template. At the end of a laboratory session, students do not have a real opportunity to explore their understanding, or to embed their learning of the process of 'doing chemistry', i.e., of pursuing investigations or, at the very least, of identifying his/her learning difficulties. In particular laboratory sessions procedures are intended to proceed smoothly with, arguably, little risk of originating any significant learning!

By contrast, if students are to engage more fully in laboratory sessions then it is important that they have opportunity to: (a) identify the main objectives of the work, (b) identify and overcome any conceptual and practical difficulties encountered, (c) plan and execute the work involved, (d) record and discuss the results and observations in their lab book (a log book, not a book of reports) and, eventually, (e) suggest practical alterations and improvements and (f) raise questions orally or through using the 'question box' or any of the desktop computers available in the laboratory rooms.

In this mode, then, it is important that laboratory work dispenses with long and complex lists of procedures with elaborate equipment, it must be based on fairly straight forward ideas and require simple equipment, easily available in the laboratory. It is also important that the work provides significant opportunities for students to really engage with the topics at hand. Lab tutors are encouraged not to 'take over' the moment that a student encounters a difficulty but, instead, to provide appropriate orientation and guidance for the student to overcome the difficulty independently. Students are asked to record observations and results in an individual laboratory book, a logbook that remains in the laboratory room as an accumulative record of the student's work. This forms part of the assessment process which, in turn, is concentrated on students' progress rather than on performance on individual lab works.

Some examples of Practical Works for laboratory classes (2nd semester 2001/2002) include:

- **Phenolphthalein** – Plan and execute experiments for observing the colour changes of phenolphthalein in the pH range approximately from pH -1 to pH 12. Among the phenolphthalein structures provided in the laboratory manual, identify those involved in each observed colour change. Write the corresponding acid-base

reactions. What is the structural feature whose presence provides colour? And what is the one that makes a particular phenolphthalein structure uncoloured?

- **Separation of substances** – Plan and execute experiments for separating copper sulphate and salicylic acid from a provided ethanol-water solution where both of those substances are in solution. Base your experimental strategy on test-tube experiments carried out to answer the following questions:

Is copper sulphate soluble in water? And in ethanol?

Is salicylic acid soluble in water? And in ethanol?

Explain your findings in your lab book.

- **Corrosion of iron** – Plan and execute experiments for studying the corrosion of iron. In particular, the planned experiments should provide clear answers to the following questions:

What is (are) the effect(s) of strong electrolytes in the corrosion process?

How to confirm that cathodic protection prevents corrosion?

(v) Mini-projects

In the first year of this research work, this initiative was undertaken as a ‘pilot’ with students from just one of the seminar-tutorial classrooms involved. The students were given 6 weeks to choose, negotiate and develop a small project on some topic of chemistry of interest to themselves. The following topics were finally chosen by 26 students: ‘Blood gases and deep-sea diving’, ‘Self-replicating molecules’, ‘Catalytic converters’, ‘Hydrogen as a fuel’, ‘CO₂ and the greenhouse effect’, ‘Catalysts based on zeolites’, ‘Magnetic Resonance Imaging in Medicine’, ‘Chemistry and the forensic science’. Work was conducted in groups of 2, 3 or 4, in their own time (outside formal sessions). During this period, each group had various sessions with teachers, in which only the students had the initiative to question their topic and the teacher would only provide appropriate orientation and guidance for the students to identify and solve their questions. The projects were then presented by each ‘project team’ to the other students and to members of staff in the department. The presentations took place on an evening over a period of three hours – with each presentation being subject to numerous questions from both peers and tutors. In some instances the presentations were

organised around a series of the team's own questions. In the second year of this project the general process was repeated, though this time other seminar-tutorial groups were invited to participate from a wider selection of topics, with a total of 13 projects being presented involving 42 students.

4. SOME OUTCOMES OF USING STUDENT GENERATED QUESTIONS

In this paper, student-generated questions are used as diagnostic of the willingness of the students to engage in classroom interactions. Particular attention has been paid to the quality of classroom interactions, the use of questions by students and their views about the course design. In addition, the students' capacity to design and present 'quality questions' during phases of their learning, and the extent to which these questions are indicative of particular styles of interaction in the classroom are also assessed. The following results refer to a sample of 100 students followed in 2001/02. Occasionally, they are compared with those of a pilot study on a sample of 32 students in the academic year of 2000/01.

In the initial analysis we adopted a bipolar taxonomy of student-generated questions that distinguishes between 'confirmatory' and 'transformation' questions. According to this taxonomy, confirmatory questions look for clarification of previous knowledge, try to discriminate fact from speculation, aim at solving specific difficulties, and ask for illustration and/or definition. In turn, transformation questions aim at reorganizing and/or restructuring the knowledge and comprehension of the learner, suggesting that he/she is apparently familiar with the subject and is able to hypothesize and deduct, looking for inferences and improvements of prior knowledge. Elsewhere (Pedrosa de Jesus *et al*, 2001), we have suggested that transformatory questions are of a higher value and quality than confirmatory ones.

Table 1 presents the number of confirmatory and transformation questions, written by students during the second semester of 2001/2002, using the question's box and the software system. As can be seen from this Table, 70% of the questions were classified as confirmatory, which agrees with the result obtained during the pilot study (69%; results not shown). A larger number of students (75%) have preferred the

question's box to the dedicated software system. It is important to note, however, that an appreciable number of students (30%) asked questions while they were away from the university, thus showing the relevance of the software system.

Insert Table 1

Table 2 shows the number of confirmatory and transformation questions per month, during the second semester of 2001/02. While the total number of questions peaks in March and May, the relative number of transformation questions per month increases along the semester, thus pointing to a relative improvement in the quality of the questions. This trend, already observed during the pilot study, lends support to the objectives of the present work and is in keeping with the occurrence, in the learning process, of a 'quantitative stage' prior to a 'qualitative stage' (Biggs, 1999).

Insert Table 2

In the second semester of 2001/02, the 'QQ-lecture' considered the topics *Acid Rain*, *Fuel Cells*, *Ozone Layer* and *Conducting Polymers*, these corresponding to previously lectured topics on Acids and Bases, Electrochemistry, Chemical Kinetics, Organic Chemistry, respectively. These QQ-lectures originated peaks in the distribution of student-generated questions along the semester (see Figure 1) and contributed to an appreciable increase in the level of students' enthusiasm and engagement in these lectures.

Figure 1 about here

Table 3 shows the distribution of questions by different kinds of classes (lab sessions, QQ-lectures, and the remaining large classroom lectures plus tutorials). As can be seen, laboratory sessions and QQ-lectures stimulated the presentation of questions, as approximately 80% of the total number of questions originated from these lab sessions or QQ-lectures. Since approximately 48% of the students did not support

their questions for QQ-lectures with the recommended readings, a large percentage of these questions (approximately 77%) were confirmatory, requesting relatively basic information on the subjects under discussion. The laboratory sessions come second in the number of questions raised, with a share of the total of approximately 33%.

Insert Table 3

Together with the results of routine student feedback on the programme, the data above suggest that the introduction of the QQ-lectures and the strategies adopted in the lab sessions were relatively successful and should be pursued with both fine- and coarse-tuning.

4. DISCUSSION

While there has always been a need to explore approaches to the teaching of Chemistry in order to maintain quality provision, a greater impetus for innovation is now manifest through the need to cater for a broader range of students and a widening of participation in higher education. The work described in this paper has been premised upon the assumption that to increase interactions between the learner, teacher and learning task is to engage the learner more fully and thereby to improve the quality of the learning experience. Three outcomes of engagement in learning have been suggested by Biggs (1982), as an increase in students' knowledge base, an improvement in motivation to learn and an increase in active learning being better than passive learning. This research has monitored five innovations in the teaching of chemistry: 'QQ lectures', 'Conference lectures', seminar tutorials, a new regime of practical work and the use of 'mini-projects'.

This curricular 'tuning' has resulted in a number of outcomes. In this paper, we have chosen one indicator of any increase in engagement to be the number and level of questions generated by student within the particular learning context. The trends in the data show that the number of 'transformative' questions increases across the semester, pointing to an improvement in the quality of the questions. In that transformation questions are associated with the reorganisation and restructuring of knowledge, this

suggests that learners are increasingly familiar with the subject to be able to hypothesize, deduct, look for inferences and make improvements in their knowledge. This increase in transformative questions, then, is taken to indicate a general improvement in these areas of learning.

The QQ-lectures, constructed as they were in direct response to students' questions, are deemed to have been successful in generating peaks in the number of student questions across the semester. This is taken as an indication of an appreciable increase in the level of student motivation and engagement in these lectures. The very 'be-spoke' nature of these lectures brings a very strong and personal dimension to the learning of chemistry and students can very readily see how their contributed questions are used as the basis for the session, illuminated through carefully chosen case studies in chemistry to explore the issues raised.

Conference-lectures have been voluntary lectures on selected chemistry topics of wide scientific, technological and social interest intended to stimulate and enhance student's curiosity in chemistry. Each of these lectures generated audiences of about 50 students – although attendance at the first of these was larger than the third. We see this voluntary attendance at these additional sessions (held in the evenings, at the end of a busy day!) as a clear indication that students were successfully drawn into the broad issues surrounding chemistry, were engaging with the subjects involved and with a 'culture of inquiry' in the department.

Mini-project sessions were a marked success, particularly in terms of increasing the number and the quality of questions in the sessions with the teacher, during poster preparation, and of encouraging peer questioning in the final poster presentation session. Group initiative and innovation in the way each poster was presented was much encouraged and proved very rewarding, especially in the second year of the mini-projects session, where several groups decided to complement their poster presentations using computer video projections.

One pause for thought here concerns the number of students (30%) who asked questions while they were away from the university through the 'remote' use of the software system. At first glance this may be taken as an unwillingness to ask questions in the give-and -take of a lecture or tutorial situation. It is more likely, however, that the

software system allows students to ruminate on their questions, to undertake reading and to tackle assignments and then to ask questions in ‘down-time’ when away from the formal situation. In this sense it is taken as an illustration of their willingness to engage in chemistry in their own self-directed time.

The success of classroom innovation is difficult to measure. Here we have used an unusual indicator – the quantity and quality of student-generated-questions. Clearly, this is just one pointer among several but, as this particular programme in undergraduate Chemistry has evolved, there has been a general increase in the ‘spirit of inquiry’ that has infected the course, as evidenced by the responses of both students and teachers. We believe this is change in a very positive direction.

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Table 1. Number of confirmatory and transformation questions, addressed by students during the second semester of 2001/2002, using the question's box and the software system.

Used instrument	Confirmatory questions	Transformation questions	Total
Question's box	109	44	153 (75%)
Software system	33	18	51(25%)
Total	142 (70%)	62 (30%)	204

Table 2. Number of confirmatory and transformation questions per month, during the second semester of 2001/02.

Month	Confirmatory questions	Transformation questions	Total
February	7	1 (13%)	8
March	92	23 (20%)	115
April	10	8 (44%)	18
May	33	30 (48%)	63

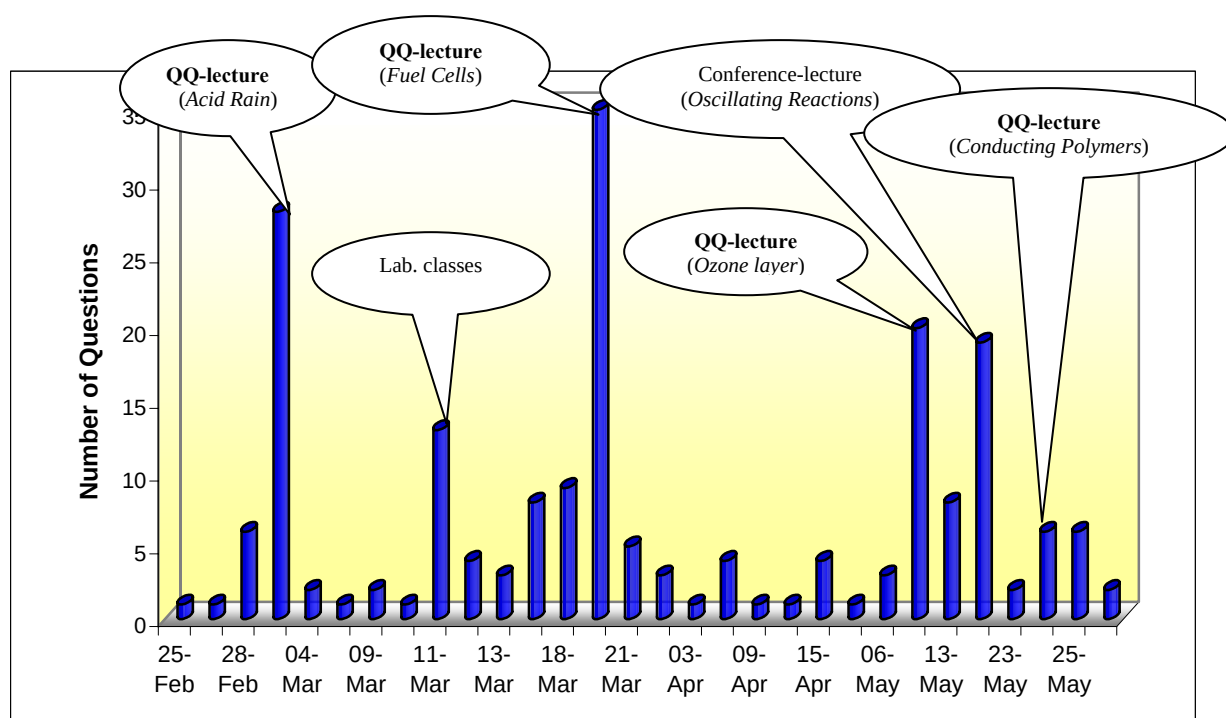


Figure 1: Daily distribution of student-generated questions, during the 2nd semester of 2001/2001.

Table 3. Distribution of questions for distinct kinds of classes.

Kinds of classes	Confirmatory questions	Transformation questions	Total
Lab sessions	46	21	67 (33%)
QQ-lectures	73	22	95 (47%)
Remaining lectures plus tutorials	23	19	42 (20%)
Total	142 (70%)	62 (30%)	204