

CHAPTER 12

FACTORS INFLUENCING THE LEARNING PROCESS IN FIRST-YEAR CHEMISTRY

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Introduction

[First-year chemistry students] think that by being in class the information is magically absorbed and stored in their brains.

This sentiment, as expressed by a first-year chemistry student at Stellenbosch University, might not come as a surprise to most academics. Convincing students to actively engage with the process of learning is not an easy task and often defeats our best efforts and purest intentions. Teaching and learning experts suggest that we can change this by changing our assessment strategies (Gibbs, 1999; Gibbs & Simpson, 2004).

There is substantial evidence that assessment plays a significant role in determining students' learning strategies, approaches and activities. Assessment strongly influences what students attend to, how hard they work, how they allocate their study time and what they can afford to get interested in (Stallings & Leslie, 1970). Many authors have cited its power to affect student learning for good or bad (Black & Wiliam, 1998; Boud, 1995; Brown, Bull & Pendlebury, 1997; Gibbs, 1992; Gibbs, Simpson & Macdonald, 2003; Ramsden, 1992; Rust, 2002). In the words of Boud (1995:35): '[S]tudents can, with difficulty, escape from the effects of poor teaching, they cannot (by definition, if they want to graduate) escape the effects of poor assessment'. The Higher Education Quality Committee (HEQC) of South Africa echoes this, calling student assessment a 'key indicator of the health of teaching and learning in Higher Education institutions' (HEQC, 2003).

Various authors (Broekkamp & Van Hout-Wolters, 2007; Frederiksen, 1984; Newble & Jaeger, 1983; Scouller, 1998; Van Etten, Freebern & Pressley, 1997) describe ways in which assessment impacts learning. The first of these is the quantity and distribution of student learning effort. The scheduling, nature, perceived importance and level of difficulty of the assessment tasks all affect students' choices in terms of when and how hard to learn. Secondly, assessment influences the resources students choose

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to use and how they choose to use them. Besides influencing what, when and how students learn, assessment also impacts learning in affective ways. Where students do not believe in a positive relationship between effort and performance, it could negatively affect their motivation to study. Similarly, the level of threat and anxiety associated with assessment tasks can also lead to positive and negative outcomes in terms of student learning.

Gibbs *et al.* (2003) mention eleven conditions under which assessment supports student learning. Amongst these are two conditions that impact the quantity and distribution of effort, namely designing assessment tasks that capture sufficient study time and distributing assessment tasks across topics and weeks. Another two conditions are concerned with the quality and level of student effort, while seven of the conditions focus on the role of feedback – the quantity and timing of feedback, the quality of the feedback and how students respond to the feedback provided.

Clearly, the assessment choices we make impact the learning choices students make. In this study, two individuals who believe in the value of classroom research – one an educational developer, the other a Teaching Fellow in a Chemistry department – decided to put this to the test in a fairly large first-year Chemistry module at Stellenbosch University. This module presents numerous challenges to the five lecturers who teach it. It serves as both a mainstream and service module with many students having to take it as a requirement for their selected (non-chemistry) study programme. Responses in the annual, institutional student feedback questionnaires repeatedly include questions about relevance to various fields of study in addition to mention of the module's difficulty and high workload. Students also highlight a lack of interest, and negative beliefs about their ability to be successful in Chemistry. A common concern amongst lecturers on the module is that very few students make any effort to stay up to date with the work during the semester. Even then, they feel, students often use a surface approach rather than trying to understand the underlying concepts. Since each topic in this module builds on the last, habits such as these are especially troublesome.

This chapter will report on two studies: one documenting the relationship between current assessment and student learning; another documenting an attempt to use assessment to address some of these problems. As part of the second study, it will discuss the choices students made in response to an intervention that was introduced to encourage more effective and consistent study habits.

Chemistry 114 context

Chemistry 114 is a fairly large module with a history of poor pass rates and unsatisfactory student ratings. Presented in the first semester of the first year, this module covers basic introductory chemistry topics such as stoichiometry, electronic structure and bonding, equilibrium, solubility and redox reactions. It is taught by a team of five academics from the Chemistry department. The students taking this module are typically divided into five groups with each of the five lecturers in the team taking responsibility for one of these groups. Formal contact sessions comprise

three 50-minute lectures per week as well as four two-hour tutorials and six three-hour laboratory sessions spread over the course of the semester.

The population of 868 students in this study included 210 students who were repeating the course, 423 (48.7%) males and 445 (51.3%) females. Students taking the module bring with them a variety of academic backgrounds, motivations and expectations. Almost 91% of the students in this study took Chemistry 114 as a pre-requisite for further study in other fields, such as biological sciences.

Assessment tasks in the module focus strongly on the ability to integrate and apply basic introductory concepts in solving specific problems (chemical calculations). The assessment consists of four tutorial tests, six practical reports, a class test towards the middle of the semester, and an end of semester examination. Figure 12.1 shows that the tutorial tests, written at the end of a tutorial session, make up 30% of the class mark with practical marks adding 20% and the class test the remaining 50%. The class mark and the examination mark contribute 40% and 60% respectively towards the final mark for the module.

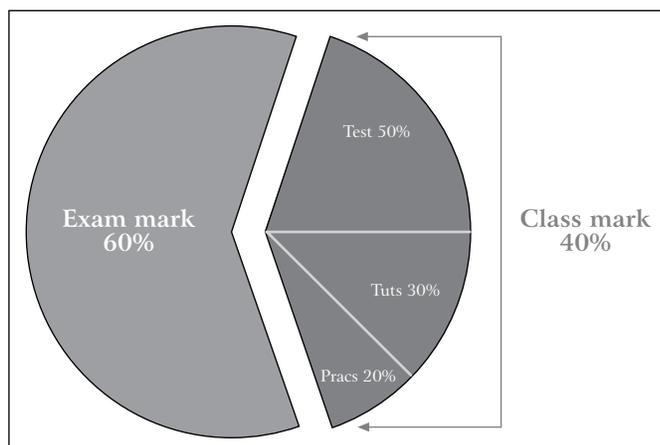


Figure 12.1 Allocation of marks used for calculation of final mark in Chemistry 114

The class test and the examination paper consist of multiple-choice and constructed response items, while the tutorial tests use multiple-choice questions only. In all of the assessment tasks there is a strong emphasis on calculations with more than 95% of the questions – multiple-choice and constructed response – requiring calculations based on the application and integration of basic chemistry concepts. The practical reports also include calculation based questions, contributing 15-50% to the final practical mark.

Two problems were of interest to this project: erratic study habits comprising short bursts of cramming prior to high stakes tests and ineffective learning methods in

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which students employ surface and algorithmic approaches (Case & Marshall, 2004). We addressed two questions in these studies:

1. What are the study habits of students on the Chemistry 114 module?
2. Can regular small in-class tests benefit students?

Methodology

Two studies were carried out. The first was a case study investigating the expected and actual study habits of students in the module. The second entailed the implementation and small-scale evaluation of an intervention: the introduction of small, formative in-class tests with one of the five class groups (N = 154).

Case study

This study focused on how students approached existing assessment opportunities. We also compared the expectations of the lecturing team about students' study habits required for success, with the study habits reported by the students.

The participants in this study included the 868 students enrolled in Chemistry 114 during the first semester of 2008 as well as the five lecturers who taught on the module.

Two data collection methods were used. A paper-based questionnaire, which contained both quantitative and qualitative items, was used to gain insight into students' beliefs and study habits. The teacher-researcher in this project also conducted individual interviews with the Chemistry 114 lecturing team, in part to form an understanding of their expectations and how that relates to what the students reported, but also to keep them informed about the study and to gain their input.

In-class tests

Small in-class tests were introduced in the hope that they would encourage consistent work and more effective study methods. Students were notified beforehand when a test was scheduled, with an indication of which concept was going to be tested. Although these tests did not contribute towards the class mark and the students were aware of this fact, the tests were marked and the marks were recorded on a register. Each test contained only one calculation-based question and took five to ten minutes to complete. Marked tests were handed back during the next lecture, when the correct answer was also explained. In addition to hopefully providing external motivation for students to keep up with the work, these tests provided students and the lecturer with immediate feedback on areas of the work that needed extra attention.

Participants in this study were one of the five lecture groups (N = 154), and thus a subgroup of the 868 students who participated in this study.

Students in the group who were exposed to the small, formative, in-class tests were asked to give feedback on this intervention via an e-mail-based questionnaire with open and selected response items. This questionnaire was administered during the second semester of 2008, a few months after completion of the Chemistry 114 module.

Data analysis

Data from selected response items in the questionnaire were analysed using descriptive statistics. Qualitative data from the open-ended questionnaire items were analysed, using the principles of thematic analysis.

Findings

Student responses to the existing assessment opportunities and the intervention were considered in terms of when and how hard they worked as well as what resources they selected and the level and kind of engagement with these resources. Lecturer opinion and expectations were then compared with these findings. In the first two sections, we will discuss how students responded to the existing learning and assessment opportunities. In the third section, we will consider their response to the intervention.

*Case study**Quantity and distribution of effort*

Students were asked to indicate the amount of time allocated to the existing learning and assessment opportunities in the module (see Appendix 1, Question 1). Their responses are summarised in Table 12.1.

Table 12.1 Time spent on different learning activities

Learning opportunity	Time spent in hours					
	0 hr	1-2	2-3	3-4	4-5	>5
Per tutorial (N=587)	15.3%	48.0%	21.6%	7.8%	4.3%	2.9%
Per practical session (N=576)	17.9%	59.5%	17.4%	2.6%	1.4%	1.2%
Class test (N=581)	4.6%	7.7%	11.4%	11.2%	12.2%	52.8%
Extra exercises per week (N=583)	35.7%	37.6%	15.3%	6.0%	3.2%	2.2%
Additional revision of theory and examples (N=583)	16.6%	38.4%	21.6%	9.6%	4.6%	6.9%

In addition, the lecturing team members were asked how much time they thought students needed to spend on the different tasks in order to be successful in the module (Table 12.2).

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Table 12.2 Expected time allocation according to lecturer team

Learning activity	Time (hrs)
Per tutorial	3-5
Per practical session	1-2
Class test	12-24
Doing extra exercises per week	2-6
Additional revision of theory and examples	1-4

From Table 12.1 it is evident that most of the students spent between 1 and 3 hours in preparation of the weekly laboratory and tutorial sessions. Thus, 77% of the students spent as much time preparing for laboratory work as the lecturers expected, with 18% indicating that they did not prepare for these events. In the case of tutorials, the picture is not quite as positive with only about 35% of the students putting in the amount of effort the lecturers had expected and 15% of the students putting in no effort to prepare for the tutorial. This is of some concern if one takes into account that the tutorial marks account for 30% of the class mark. With the class test, matters are even worse with most students falling far short of the lecturing team's expectation (Table 12.2) of 12 to 24 hours of preparation. Almost half of the group indicated that they spent less than five hours preparing themselves for this crucial assessment opportunity.

As predicted in the literature, most students spent very little time, over and above test preparation, on reviewing their work and staying up to date, with 37.6% (N = 583) spending less than two hours per week on this and 35.7% affording no time to it.

The findings from this part of the study confirm previous findings (Black & Wiliam, 1998; Van Etten *et al.*, 1997) that student effort – both in terms of quantity and distribution – is related to the nature and scheduling of the assessment tasks. Most of the students only worked in preparation for tests. Furthermore, the effort they put into preparing for the different tests seems to be influenced by their nature and importance. Though the amount of time students reported spending on preparation for the class test was less than that expected by the lecturing team, this is still the assessment opportunity most students spent the most time on (see Table 12.1). One reason for this might be that the class test contained a mix of constructed response and selected response items, as opposed to the tutorial tests, which contained only multiple-choice items. This is in line with the findings of Scouller (1998) and Van Etten *et al.* (1997) who referred to a greater reliance on low-level memorisation in the case of multiple-choice tests. Fransson (1977) also mentions that the degree of threat has an impact on students' response to assessment tasks. In this case, each individual tutorial test, contributing only 7.5% to the class mark, represents a much lower degree of threat than the class test, which counts for half of the class mark.

The selection and use of available resources

Students can approach chemistry by 'rote learning' theoretical concepts or by practising the application of the concepts through doing exercises. Lecturers in Chemistry 114 emphasise the importance of doing exercises in this module. To this end, some of the lecturers give students a list of appropriate textbook problems to try after each lecture. In addition to the examples and exercises in the textbook, students can access tutorial questions (which are available a week before the start of the tutorial) and old test and exam papers online. This leaves no shortage of exercises to utilise.

Van Etten *et al.* (1997:202) found that students knew what was required for success, but that test preparation is complex, 'involv[ing] strategic coordination of a number of resources'. Similarly, the Chemistry 114 students knew what they had to do to be successful. When asked (in the second questionnaire) how important they thought it was to do exercises in order to prepare for the class test (see Addendum 1, Question 2), 92.6% (N = 752) of students stated that it was very important and 85.8% (N = 754) said that they were going to do *many* exercises (more than one per section) in order to prepare for the class test (see Addendum 1, Question 3). Sadly, this did not translate to reality. In subsequent questionnaires, less than 30% of the group indicated that they tried working on problems or using the formative assessment opportunities provided in the module. When given a list of resources (PowerPoint lectures, theory sections in text book, own summaries, completed examples, tutorials, exercises, old question papers) and asked which one they used *the most* during their preparation for tutorial tests (see Addendum 1, Question 4), only 3.3% (N = 583) chose exercises while just 4.9% (N = 586) indicated that they primarily used exercises during their preparation for the class test. These resources can be separated into two broad categories: those that require active work using application and integration of basic concepts (examples, tutorials, exercises, old question papers) and those that do not necessarily require active work of this nature (PowerPoint lectures, theory sections in text book, own summaries). When these resources are separated into these categories, most of the students (74.7%, N = 583) chose the latter option which could be handled with less cognitive effort (PowerPoint lectures, theory sections in text book, own summaries).

A number of factors might play a role here. It has been noted that students are more likely to engage with material that featured in class discussions (Van Etten *et al.*, 1997). The nature of the tutorial tests, which might be perceived to be on a lower cognitive level (Scouler, 1998), might be another factor to consider in the choice of material and study methods. Van Etten *et al.* (1997:209) claim that the format of the upcoming exam 'shapes study and affects performance'. In addition, it has been argued that high volumes of work can result in lower levels of cognitive engagement and drive greater selectivity in terms of resources used (Ramsden, 1984). Students in one study (Van Etten *et al.*, 1997) reported greater motivation to study for material of medium difficulty. When the content is seen as too difficult or when the volume becomes too overwhelming, as might be the case here if one considers the opinions expressed in student feedback surveys, it can negatively impact their motivation to study it.

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Reported strategies for dealing with high volumes of work included skim reading and reading what is most informative (Van Etten *et al.*, 1997).

Case and Fraser (2002:42) also found that having to cope with high volumes of work 'would appear to counter the development of conceptual approaches to learning and learning outcomes that include conceptual understanding'. This might help to explain their choice to focus on the PowerPoint presentations and theory sections, which might be perceived to require less cognitive effort.

In-class tests

The in-class tests can be seen as a version of the 'two stage tests' mentioned by Gibbs *et al.* (2003). By using regular, small in-class tests with immediate feedback, it was hoped that the quantity and distribution as well as the quality of student effort could be improved. This intention also captures a number of the eleven conditions under which assessment supports learning (Gibbs *et al.*, 2003), including the distribution of effort across weeks and topics, capturing sufficient study time, engaging students in productive learning activities and providing quick feedback.

In the third questionnaire, the entire group of students – including those who were not exposed to frequent, formative in-class tests – were asked whether they thought such tests could help them identify areas of learning in need of development (see Appendix 1, Question 5(c)). Most (86.1%, N = 563) indicated that they thought such tests could help them in this way, and although 91% of them preferred the dates of these tests to be announced beforehand (see Appendix 1, Question 6(a)), 63% thought that unannounced tests would lead to improved concentration during lectures (see Appendix 1, Question 6(d)). Interestingly, 63% of students felt that they would study for these tests even if they did not contribute to their class mark (see Appendix 1, Question 6(c)).

Students in the group in which the small in-class tests were used (N = 154), were asked what they thought contributed to their pass rate (see Appendix 1, Question 7), which was 14% higher than that of the rest of the group (N = 714). The majority (81%, N = 2) of the respondents indicated that they thought that the small in-class tests contributed meaningfully towards the higher pass rate of this group, while 44% selected the frequent small in-class tests as the most important factor (see Appendix 1, Question 8) contributing to the higher pass rate.

Students identified at least six reasons why they chose to pay attention to the regular class tests (see Appendix 1, Question 9). They mentioned that the amount of work that had to be prepared for each of these tests seemed more manageable, they knew exactly what to expect, the material was still fresh in their minds at the time of the test, their marks were recorded by the lecturer, the results were available almost immediately, and the tests provided them with valuable feedback.

Although this feedback was not anonymous, it was requested a few months after the students had completed Chemistry 114. Most of the respondents also did not intend to continue with Chemistry. Thus, the risk of bias introduced by the fact that it was not anonymous was hopefully lowered.

Discussion

The purpose of the intervention tested in this study was to enhance consistent, effective work – what Chickering and Gamson (1987) call ‘time on task’. Citing the work of other authors, among which a meta-analysis of forty relevant studies by Bangert-Drowns, Kulik and Kulik (1991), Black and Wiliam (1998) suggest that frequent testing can enhance learning. In line with this claim, it was hoped that the small, frequent in-class tests would encourage students to review their work on a regular basis and adapt their study habits. Feedback about the small in-class tests (e-mail survey) seems to indicate that it achieved this purpose. In the words of one student: ‘The small in-class tests force you to review the work every day which one wouldn’t do under normal circumstances’

In addition, it was hoped that the nature of these tests would encourage students to aim for understanding of the concepts rather than adopting inappropriate surface approaches. To this end, these tests used calculation-type questions similar to those in the class test and formal exam. We also believe that the availability of feedback very shortly after the tests were written, aided in achieving this purpose. Not only did it alert students to flaws in their preparation and areas that needed more attention, but it did so while the work was ‘still fresh in their minds’, in the words of one the students. In responses to the e-mail questionnaire, students highlighted the fact that the feedback provided on these tests was of great value, listing it amongst the reasons why they paid attention to these purely formative assessment opportunities. Gibbs *et al.* (2003) argue that students are more likely to use feedback to work that will be tested again. They suggest the use of ‘two staged classroom tests ... where the first stage is formative and the second stage ... is summative’ in which students can use the feedback from the ‘formative stage to orient and focus their study behaviour in preparation for the summative stage’ (Gibbs *et al.*, 2003:2).

What might come as a surprise is that students in the intervention group reported taking these small in-class tests seriously, given that they were purely formative in nature. Summative assessments have often been mentioned as a ‘salient motivation’ for studying (Van Etten *et al.*, 1997:208). The students in the Van Etten *et al.* (1997:200) study were ‘emphatic that examinations *per se* motivate studying’, adding that most active studying would cease in absence of examinations. However, in a comprehensive review article, titled ‘Assessment and classroom learning’, Black and Wiliam (1998:24) state that ‘there is evidence from many studies that learners’ beliefs about their capacity as learners can affect their achievement’.

If we look closer at the context of this study and the rest of the Van Etten *et al.* (1997) findings, the choices the Chemistry 114 students made in this module start to make some sense.

In the student feedback collected for Chemistry 114 in 2008, the students referred to the study material as ‘academically challenging’ and added that ‘students struggle with Chemistry’. They also mentioned the workload in comments such as: ‘can possibly work a little slower so one can keep up, especially with the theory’ and ‘... the work covered in some lectures is far too much to grasp, perhaps, pace should be essential’.

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Furthermore, students mentioned an inability to see the relevance of this module to their selected courses of study. Various comments referred to this issue, with statements such as ‘this module is unnecessary for my course of study!!!’ and ‘I am unfortunately forced to take this module and I hate it! The lecturer is very good; the subject just does not interest me at all.’

Van Etten *et al.* (1997) show that students study less for subjects when they fail to see the relevance of the work, find it uninteresting or when the subject is not their major. In addition, when the volume or difficulty level of the work is perceived as too high, it can negatively impact the study time. When students start to doubt that the time they have to invest in learning the work will pay off, they might also decrease the study time for that subject. We can add to these factors, which have all received mention in the student feedback for Chemistry 114, the fact that this compulsory module often stands between them and doing what they really want to do. The following comment from the 2008 student feedback for the module clearly illustrates this: ‘Subject not relevant to some courses, take this module out of Conservation Ecology. It will take me 10 years longer with this subject in my course.’

If we now return to the small in-class tests, and consider what students had to say about them, we can see how it unintentionally addressed a number of these issues at once. On the one hand, the small in-class tests reduced the immediate workload by breaking the work into manageable chunks. In telling students exactly which concept to concentrate on and aligning it with the discussions in class, these tests also limited the difficulty level. Together, these factors could reduce anxiety and increase students’ sense of agency, fostering a belief that studying can lead to the required outcomes. This is also in line with findings that students work harder for ‘medium difficulty’ work which ‘would pay off without taking too great a toll on their other commitments’ (Van Etten *et al.*, 1997:208).

On the other hand, the small in-class tests strangely enough raised the risk of exposure. Unlike the tutorial tests, these were marked by the lecturer who also kept a register of the marks. Tutorial tests, meanwhile, were marked by the thirty-four tutors on the module, and the marks were fed into a central system without being passed to the lecturers. In the e-mail feedback on the small in-class tests, students referred to the recording of their marks by the lecturer as having an impact on their choice to take these tests more seriously.

Although the two studies we are reporting on resulted in different data sets that cannot be related in any way, an understanding of each helped form and inform our understanding of the factors involved in the other.

This study also highlighted a new concern in the module: the possibility that tutorial tests, besides not reaching their purpose, might actually encourage ineffective study habits. If multiple-choice tests do encourage surface approaches as has been suggested (Scouler, 1998; Van Etten *et al.*, 1997), exposing students to four such tests, and no other form of summative assessment, in the run up to the class test, might create unrealistic expectations. It has been argued that students sometimes use

the tests early in the term to determine how future tests should be approached (Van Etten *et al.*, 1997). Case (2004:146-148), for example, reported the unwillingness in one candidate to adapt his study habits after an 'easy' first test, even when subsequent tests were failed,

Conclusions

This study shows the value of using assessment to encourage consistent work and more effective study habits, but it also highlights various complicating factors including contextual and affective issues.

Using assessment in this way has improved learning in this study in at least two ways. It provided an extrinsic motivation to encourage daily reviewing, at least for some students, and it afforded students with a sense of control over the work. Students in the Van Etten *et al.* (1997:200) study indicated that 'whether they study or not depended more than anything else on whether they believed studying would make a difference in how well they did'.

However, using assessment to drive learning is not a straightforward process. This study highlighted many competing factors that can mediate student choices. In this case, factors such as workload, level of difficulty of the work, test format, risk of exposure in different assessment opportunities, compulsory nature of the module for many students and the inability to see the relevance of the topics, all seem to play a role in what students decide to do.

In the words of Van Etten *et al.* (1997:194): '... study activity and achievement both depend greatly on the characteristics of courses, consistent with the conclusion that studying and learning are situationally sensitive'.

Another positive result of this study was a re-iteration of the value of teacher-researchers doing classroom research at first-year level (Cross, 1996). Being involved with the teaching and administration in this course afforded the teacher-researcher in this study with the chance to test in-class initiatives and led to a unique understanding of the issues and difficulties in this course. Teacher-researchers are also perfectly placed to respond to the findings of classroom research.

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Appendix 1: Selection of relevant questions from the questionnaires

Questions 1 to 6 were from the paper-based questionnaires while Questions 7 to 9 were used in the e-mail questionnaire.

1. Time allocation for Chemistry 114	None	1-2 hours	2-3 hours	3-4 hours	4-5 hours	More than 5 hours
a) How much time did you on average spend on preparation for each tutorial session?						
b) How much time did you on average spend on preparation for each practical session?						
c) How many hours did you more or less spend on preparation for the class test?						
d) How much additional time did you on average spend on Chemistry 114 each week (preparation for tutorials, practicals and class tests excluded)?						
e) How much time did you on average spend on working out examples each week (tutorials excluded)?						
2. How important do you think it is to do your own exercises in order to prepare for the class test?						
Very important		Slightly important		Not important at all		
3. How many exercises do you plan to do in order to prepare for the class test?						
Many (more than 1 per section)		Few (1 per section)		None		
4. Material used during preparation						
a) What did you use the most during preparation for the tutorial tests?						
b) What did you use the most during preparation for the class test?						

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5. Small in-class tests	Yes	No	NA
a) Has your lecturer let his/her students write regular small in-class tests thus far?			
b) If so, did you prepare for it (in the case where it was pre-announced and not an unprepared test)?			
c) In the case where your lecturer gave small in-class tests, was it possible for you to conclude from this whether you understood the relevant wo			
d) Would you prefer to write such small in-class tests (counting 1 or 2 marks) on a regular basis (average once a week)?			
6. Small in-class tests	Yes	No	
a) If you wrote small in-class tests on a weekly basis (1 or 2 marks) in Chemistry 114, would you prefer that they were announced before the time?			
b) Would you have prepared for the announced small in-class tests if they had counted towards your class mark?			
c) If the small in-class tests did not count, would you still have prepared for them?			
d) If the small in-class tests were unannounced, would you have paid better attention in class than if there were no small in class tests?			
7. Do you think that the small in-class tests (1 or 2 marks), which were written during lecture periods, made a meaningful contribution towards the much higher pass rate?	Yes	No	
8. In the case where you have answered 'yes' in the previous question, would you regard the small in-class tests as the most important contributing factor towards the higher pass rate?	Yes	No	
9. Any comment with regard to the small in-class tests?			