Paper

An Interactive Working Group in Chemistry used as a Diagnostic Tool for Problematic Study Styles.

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Abstract
Students entering university were tested for their subject knowledge and learning styles. Students with low scores on both tests were advised to follow a process-oriented remedial instruction by means of Interactive Working Groups (IWGs). In reality a mixture of students participated which favours student interaction and thus learning. The general aim for all IWG's is to generate autonomous study skills in particular science disciplines. In this article, the first session of an IWG developed for the general chemistry course is described. It is organised at a very early stage of the academic year (4th week). Its purpose is to evaluate students' text analysis and comprehension skills of particular basic chemical concepts appearing in a text chosen for study. The text is part of their textbook and the subject is *stoichiometry*. Three activities in this IWG have been examined: their general study skills, their test results assessing basic chemical knowledge, and their ability to interpret textual information. For the latter we compared each student's scheme with that of an expert. It was found that students' performance on the assignments corresponding to these three activities could be of predictive value in identifying a surface approach to learning at an early stage.

Introduction

A major purpose of science education is to have students construct a deep conceptual understanding of any scientific topic studied. This cannot be achieved if students do not acquire higher order cognitive skills (HOCS)[1] that include the ability of asking questions,[2] solving problems, decision making and critical system thinking.[3] These skills can be developed through an appropriate process-oriented form of instruction, one that emphasizes the development of HOCS through independent learning and active participation in the instruction-learning process. The Learning and Guidance Centre at the Vrije Universiteit Brussel, a unique concept in Belgium, developed a process-oriented instructional method called Interactive Working Groups (IWG) for several science disciplines. The major goals of IWGs are the promotion of in-depth learning, knowledge construction, self-regulation, and awareness of misconceptions by the training in general and specific learning skills in a content-specific context (in science). Depending on the content and/or identified learning problems, more emphasis is laid on one of these goals. One particular IWG is the subject of this article. IWG's are based on the socio-constructivistic model.[4] According to this model the learner builds his own knowledge through the interaction with the environment; in the case of IWGs a two-way communication between students and students-instructor is represented. It is known that a two-way kind of interaction is far more supportive of meaningful science learning than a unidirectional speech.[5]

Wellington and Osborn[6] described several structural experiences and tasks to support students' interactions. They suggested the use of collaborative concept mapping activities, structured critical instances involving common misconceptions and the use of directed activities related to texts, to structure and guiding students in small-group activities and discussions. The use of visualisation techniques is a strong approach to encourage students to adopt more effective and meaningful processing strategies. It includes teaching awareness of text structure for generating explanations.[7]

Students participating in the IWG discussed in this paper were asked to demonstrate their understanding by making use of text structure visualisation techniques. The reason of using them is many-fold: students discover another study technique, the instructor has a quick tool to evaluate students' text comprehensive skills and active student participation is demanded because it is *their* scheme.

The learning process is also influenced by the way new information is passed through the filter of a learner's prior knowledge and experience.[8] Consequently, when prior knowledge is involved in the creation of meaning, what the learner already knows is of central importance.[9] "*Ascertain this and teach accordingly,"* states the oft-quoted assertion of Ausubel.[10]

Background to the problem and aim of this study

Flemish science students are not selected for entry to universities by means of national exams. As a consequence, many of them cannot (immediately) cope with the high demands of university studies. Due to the bachelor-master reorganisation, the semester is reduced from 15 to 13 weeks. It becomes at this stage even more important to identify learning deficiencies as early as possible. The question is, on the one hand how to identify students at risk in a very early stage, and on the other to prepare students for assessment that takes place three to four months after enrolment. On the level of the general chemistry course, we have identified certain factors that, we believe, influence the success rates of our students.

(a) *Prior knowledge*

To identify deficiencies in chemistry content knowledge, the Learning and Guidance Centre organises prior knowledge tests of chemistry on students' entrance day. Its main goal is to make students aware of the extent, limits and accuracy of their prior knowledge. The set-up and the evaluation of the prior knowledge test of chemistry show common elements with the chemistry exams: open questions that test for accurate recall of concepts represent a minor part and the major part tests their problem solving ability. Over a period of three years, we have found that the initial prior knowledge defines for a large part their performance on the mid-term exam of chemistry that in its turn influences the end of term exams.[11]

(b) Learning environment

Group interviews with weak and with good students reveal that the students' perception of the general chemistry course before the examination is not in accord with the complexity of the subject matter. They perceive the chemistry learning environment as well structured. The chemistry content is very well explained in the lecture sessions and extensively covered in their syllabus. Problem solving sessions and laboratory activities are fully integrated into the course set-up. The pace of the lectures and problem solving sessions is well judged. Once the exams are approaching or have been taken, many students realize that chemistry is more complicated than they had thought. Some of them understand that their struggle is due to their textbook; a textbook that extensively covers all topics in detail makes students think it is easy to study. It also seems that lectures give those students a (false) feeling of understanding which leads to procrastination. Because they think they understand and know that the content is covered by their textbook, they go home (with confidence) and devote their attention to courses that are perceived as more difficult or demanding (assignments with deadlines given after each lecture). Excellent students focus simultaneously on all courses.[12] The procrastinators do not feel the need to combine and correlate the bits of information from several lectures.

(c) Cognitive and meta-cognitive abilities

One of our tools for acquiring information on the students' cognitive and meta-cognitive abilities is the Learning Style Questionnaire of Jan Vermunt.[13] Students are invited to discuss their results and are asked whether they recognize themselves in the learning style outcome. In the case of agreement and low subscale scores for the motivational and self-regulated subscales, we strongly advise them to join the Interactive Working Groups.

In one of our quantitative studies we found that many first year students believe that finding a correct numerical solution means that one understands the theory. Their strategy consists of doing as many exercises as possible. But in the end, it turns out that a lack of study time prevents many of them to reach this goal.[12] Upon analysing students' written exam papers, we had the feeling that failures could also be attributed to weak text-interpretation abilities. This observation is also corroborated by recent studies revealing that middle school students' knowledge about reading science, meta-cognitive awareness, was only partially developed and the strategies they used to repair comprehension failures were limited and not well adapted to science texts.[14]

Both learning style inventories and prior knowledge test results are helpful indicators for potentially problematic learners, but exact correlations between an individual learning style and exam performances cannot be drawn. For instance, some of our gifted students give themselves low scores on the self-regulation subscales and some students who turned out to be weak gave themselves very high scores. What these learning styles also do not tell us is what students exactly do when studying a (chemical) text. What do these students consider as important paragraphs, do they make links between concepts seen in earlier chapters? How do they interpret the given information, for example? Do they try to understand concepts by looking for concrete examples? The IWG under discussion, the first in a series, has the purpose to evaluate students' text analysis abilities and their understanding of particular basic chemical concepts appearing in the text to be studied. This IWG should make them aware of their shortcomings. The tool that we use for this evaluation is a student scheme that has the purpose to display the students' comprehension of the logic and philosophy of the author's text. Details are to be found in the *Instructional methodology section*.

In the *Results section*, student responses are related to their end-of term-exam of chemistry performance. We expect to see differences in assignments between gifted and less gifted students. This correlation should allow us to find out if this IWG could be used as a complementary diagnostic tool in combination with the prior knowledge test in chemistry and the Learning Style Questionnaire of Vermunt. The *Discussion section* includes some advice for the use of this particular IWG as a diagnostic tool.

Instructional methodology

Interactive Working Groups; some history and general aims

Originally created as a tool to remedy problems in the transition from secondary school to university, an interactive working group (IWG) is a process oriented teaching method. It has first been developed for the general physics course. Evaluations in the past[15] have shown that IWG participation in physics may lead to better scores in examinations and induces positive effects on the learning approach. Due to these results, other disciplines such as mathematics, biology, and later on chemistry, followed and created content-specific IWG sessions. Participation in a series of sessions is a prerequisite to overcome identified learning deficiencies. However, depending on the academic staff, some disciplines do not require attendance as in the case for chemistry. The IWG sessions are open for any student but active participation is demanded of those who attend. Advice to participate is only given to those students whose performance in the chemistry prior knowledge test was below university entrance level, in combination with a problematic learning style. Students with better prior knowledge scores or less problematic learning styles who choose to participate are thus a self-selected group. Such a mixture of potentially better and weaker students allows for better student interactions.

The IWG instructor acts as a guide rather than a teacher, observes misconceptions, provides tools to enhance autonomous thinking and creates, through interaction, an atmosphere in which students feel encouraged to participate.

All IWGs are organised in parallel with regular studies. Each session takes about two hours and a maximum of fifteen students is allowed in each group. The IWG subjects refer to the lectures and seminars that were given prior to the IWG-session. The Faculty of Sciences recognizes the merits of the IWG-sessions and therefore makes slots available on the students' weekly timetable.

Chemistry Interactive Working Groups

Several IWGs for chemistry have been developed. Their subjects are stoichiometry, the historical evolution of the atomic theory, phase diagrams, chemical equilibrium applied to Brønsted acids and bases and an organic chemistry theme about aldehydes-ketones-carboxylic acids. The main purpose remains in-depth learning. Problem solving is not part of the chemistry IWGs, as we believe that text comprehension skills and concept understanding prior to problem solving skills need to be taught first. Problem solving activities are in any case embedded in the regular curriculum. All IWG sessions use the (Flemish) textbook of general chemistry.[16] Five sessions gradually build on each other; while the first two sessions deal with text analysis and content structure, the following IWG's focus more on critical thinking.

In the Learning and Guidance Centre (LGC) students find the registration list and a specific preparation task.

Enhancement of self-regulation activities

The chemistry IWG instruction is based on the general model as developed by the LGC and slightly adapted to the model of self-regulation by Zimmerman.[17] He describes self-regulation as the degree to which individuals are metacognitively, motivationally and behaviorally proactive participants in their own learning process. The self-regulation process involves three phases – forethought, performance and evaluation – that the student applies repeatedly during learning.

The aim of forethought is to guide both the mind and the performance in any specific task, and to plan future actions. Performance consists of the execution of the activity, controlling not only every aspect involved in the development of the activity, but also those factors that may affect specification and distribution of time and effort. Evaluation refers to the phase subsequent to the learning effort; that is, the analysis of whatever occurred, the results obtained and the relationships between that particular activity and other similar ones. However, the acquisition of this skill is not necessarily associated with natural development. As with any other capacity or content, it should be explicitly taught.[18] In this IWG, the first in a series, we apply Zimmermans' ideas to see what students plan to do (the forethought part) and how they implement their ideas (the performance part). Tools to help them are offered in this part. The evaluation part is merely to let students discover their own limits, i.e. their text interpretation skills.

Subject: Stoichiometry

The IWG under discussion has been chosen because it is part of the secondary school curricula. It is organised at an early stage (4th week) of the academic year. Therefore, our conclusions will reveal students' study approaches from secondary school. The subject was also covered (merely as a review of the secondary school content) in the university lectures and problem solving seminars shortly before this session. We expected our students not to experience difficulties with this concept. Students had to read seven pages in their textbook as preparation assignment at home. They had to bring their textbook to the session. To get insight into students' text analysis and comprehension skills, we gave them in the IWG session several assignments, of which the final one was to structure the 7-page text on one page of A4 by making use of visualisation techniques.

Ideally, training in mapping techniques should have been provided, but a full college timetable prevented such an initiative. Therefore, prior to the drawing activity, the text was fully analysed by group discussion. A demonstration and explication of different scheme-techniques, i.e. concept maps[19] and mind maps[20] was also given. This should provide students with ideas. We briefly explained to them the differences between the two techniques. Concept maps have a structure similar to that of mind maps in that they show main ideas and secondary ideas linked to a topic. The first strongly resembles a linear and hierarchical structure and makes no use of the whole brain, while mind mapping uses both sides of the brain, lets them work together and thus increases productivity and memory retention. Mind maps connect ideas and concepts with a topic displayed as a graphical pattern, often as an artistic image. We were guided by an article where mind mapping is used as a tool in mathematics education.[21] Students decide then individually how they want to represent the text visually on one page. They are asked to choose a theme that covers best the content of the seven pages of study. By placing this in the middle of their paper they all have the same starting point.

Feed-back on the scheme

A drawing technique such as concept mapping is used in many cases to assess students' progress in learning.[22, 23] However, this IWG tests how far an individual student has mastered the content of a given text when several different teaching activities, such as lectures and problem-based seminars, have been organised. Schemes are quickly evaluated by comparing each student's scheme with a scheme produced by the instructor, who needs to be a content expert. The instructor's scheme has been approved by the author of the text. Such a scheme could be regarded as an expert link matrix.[24] This assessment method consists of a process in which one or more experts on a given topic produce an exhaustive set of possible relationships between each pair of concepts in the allowed set. These possible relationships can then be categorized in various ways. In our expert link matrix, we distinguish three broad characteristics: formal descriptive, explanatory and procedural (summarised in Table 1). Differences in these characteristics in the students' and the expert's scheme are discussed with the students.

Structure

Because this IWG is the first in a series we start the session with a general introduction of about 5 minutes. In brackets: the role of the instructor and time allowed for each stage.

Forethought (15')

Emphasis is placed on active student involvement on what students are planning to do. A two-minutes questionnaire (shown in the *Results section)* is handed out, followed by discussion. Students listen and add comments to each other's responses as an opportunity to hear how others plan.

Performance (1h 30')

Text-analysis (30'): we tell students that a good basis of critical text analysis is to ask oneself continuously three types of questions: *what* is the author trying to tell us, *what* does a concept mean. Then they should ask *why* this concept is under study with reference to former and later chapters or paragraphs, and *how* a concept is translated into practical use. Each paragraph of the text is discussed by continuously asking *what, why and how*? Students can look forwards and backwards in the textbook, because they have to bring their textbook to the session and this IWG is performed after the lecture covering stoichiometry. This text analysis part is performed by group discussion regulated by the instructor.

Test (15'): to monitor their understanding and use of chemical vocabulary and to provide feedback. This test is shown in the results section.

Demonstration (instructor, 10') of different sorts of schemes in different areas with explanation of the benefits, i.e. an example of a mind map made by a doctor showing a patient's medical history, a concept map of a redox reaction and another concept map showing relationships between formulas in classical mechanics.

Design of scheme (35'): students draw their scheme limited to one page.

Evaluation by self-explanation (15')

In this part the instructor uses the expert scheme to check whether the students' schemes are a schematic translation of the text. Attention is given to how the *what, why and how* questions are represented in their scheme. The best scheme is demonstrated and explained by the student to the whole group.

In this two-hour session, instant feedback is given during the discussion sessions. Some students are reluctant to talk and discuss in public. Therefore, individual feedback on the basis of their written assignments is provided after the IWG-session. By means of a check-list (displayed in Tables 1 and 2) feedback takes a minimum of five minutes per student.

Table 1: Checklist for fast feedback of a scheme's content:

Column 1 represents three scheme characteristics: a descriptive level ('*what*' questions), a procedural level ('*how*'questions) and an explanatory level ('*why*'questions). In column 2, the main paragraphs corresponding to each characteristic level are represented. In column 3, subparagraphs corresponding to the main blocks are given, while in column 4 text details are represented. The whole table has to be read from left to right. Codes are used to facilitate discussion.

Scheme Characteristics	Level content	Sublevel content	Sublevel content details
Descriptive: What *(is this paragraph about?)* (I)	Definition of a chemical equation (I.1)	Explanation by illustration (I.1.1)	Copy of the handbook (I.1.1.1) Student demonstrates his/her understanding by choosing another example of a chemical equation not given in the handbook. (I.1.1.2)
		Explanation in words such as: (I.1.2.)	Reactants → products are represented by their molecular formula (I.1.2.1), physical state symbols (I.1.2.2.), coefficients ≠ subscripts (I.1.2.3.)
		Balancing a chemical equation (I.1.3.)	Definition (I.1.3.1) Dalton (I.1.3.2) Two levels of interpretation and use (macro, micro) (I.1.3.3)
Procedural: How *(does one write a chemical equation?)* (II)	Balancing a chemical equation (II.1)	Demonstration of 3 techniques (II.1.1)	comment: never change the indices. (II.1.1.1)
Explanatory: Why *(does one need a chemical equation?)* (III)	Stoichiometric calculations (III.1)	Procedure: quantity A → mol A → mol B → quantity B (III.1.1) Three conditions (III.1.2)	III.1.1.1. limiting reactant III.1.1.2. stoichiometric ratio
	Application (III.2)	Examples (III.2.1)	

Table 2: Concept checklist with cross-links between descriptive and procedural scheme characteristics. Codes in the second column refer to Table 1

Concepts (IV)	Relationships between characteristic elements corresponding to a concept.
1. macroscopic use of a chemical equation (IV.1)	IV.1: Linking macro interpretations (I.1.3.3) to calculations (III.1) and applications (III.2)
2. law of conservation of matter (IV.2)	IV 2: Linking Dalton (I.1.3.2) to III.1.1 (Procedure)
3. stoichiometric ratio (IV.3) 4. limiting reactant (IV.4)	IV.3 and IV.4: Linking I.1.3.1 with calculations (III.1) and applications (III.2)

Results

Students enrolled for bio-engineering, biology and chemistry courses are the subject of this analysis. Their chemistry course books, evaluation criteria and teaching staff were the same. We received partial or complete assignments from only seventeen students, who are half of the attendees. We compared the students' own accounts of their study processes, their test and scheme results and correlated them with their chemistry exam results. We could identify three groups: those who failed on almost all mid-term exams and had to restart the first year [coded as *x*-students (8)], those who performed well [coded as *y*-students (7)] and those who failed at the end of term exams in June but resat successfully in September [coded as *z*-students (2)]. We mention that four *x*- and two *z*-students' scored below 40% on the prior knowledge test. All *y*-students performed much better.

We first report the questionnaire and the students' responses to it, followed by the test results. The last section analyses different levels in each scheme: descriptive, explanatory and procedural.

(a) Questionnaire results (from the forethought part)

Q1: Describe your study process before you draw your scheme.

Q2: What could be the benefits of a scheme? Give your personal opinion.

Q3: How will your scheme look?

The responses from *x*-and *y*-students are presented separately. Students coded *z* did not hand in their answers

Students' responses:

Q1: Study process

x3: "Scan quickly"

x4: "I look for particular expressions, the content's construction, comments and procedures."

x5: "Distinction of main and side topics, writing down main topics to link them possibly."

x7: "Reading the title, possibly subtitles. Count pages of sections. Scan quickly text by skipping figures, tables. Then reading, reading and again reading. Finally, look for relationships between topics."

x8: "Reading, underlining main topics, writing down definitions, formulas. Marking relationships, illustrating with examples."

x9: "Reading, underlining important topics, finding key terms and looking for relationships.

y4: "I should first read and underline the main issues. Then I should write these down to find relationships."

y5: "I look for the main issues. Then I read the important comments such as ...but not applicable in case of .... I look for relations between the main issues in order to get a better structure [in the scheme]. I use examples to illustrate concepts."

y6: "I read - underline main issues - look for structure and write it down."

y7: "I look for structure by reading and underlining. I look for important words."

Q2: benefits of a scheme

x3: "It [=a scheme] gives a better understanding of the theory and the relationships between the main topics."

x4: "Structure, relationships, easy to revise by key terms."

x5: "Reduction of content material. A scheme is an overview of the content and it prevents you from paying attention to less important topics."

x7: "It's easy to search certain topics."

x8: "All important topics are grouped together. Details are thrown away to better understand the content."

x9: "It serves as an abstract, it gives an overview and it easier to rehearse.

y4: "A scheme represents the structure of a text. Topics are linked and only the main topics are represented."

y5: "It's an overview of the content and easy for use in revision."
y6: "It's an overview and relationships are visually represented"
y7: "It's an overview, there is a structure and it controls" [what??]

Q3: visual representation
x3: no answer handed in
x4: "Mind map"
x5: "Subject title, abstract of the most important topics"
x7: "A content table"
x8: "Concepts, definitions and arrows"
x9: no answer handed in
y4: no answer handed in
y5: "Use lots of space"
y6: "Structure and colours for relationships"
y7: "Key terms, arrows and distinction between main and side topics by use of different layers".

Y-students describe their study process in terms of the following actions; they read, underline, look for relationships between topics and try to discover structure in the text. Their response style is quite alike: brief and it contains all necessary elements of their study process. Just one student uses a conditional tense (*y4*); indeed she never made a scheme, but it does not prevent her from having ideas. Some of these students go even further and consider comments as part of their scheme or try to illustrate the content. One constant of a scheme is that it must give them an overview. Running ahead, their scheme is a translation of their thoughts.

X-students are more varied in their responses. Many of them give long (*x7, x8*) or extremely short (*x3*) answers concerning their study process. Analyses of the content of their answers points out that many use a surface approach to learning, as defined by Entwistle;[25] i.e. scanning quickly, counting pages, writing down main topics to link them, *possibly*. The benefits of a scheme are as good as its creator's understanding of the content. Students *x5*, *x8* and *x9* serve as illustrations: for them their scheme must focus on important topics but in reality their scheme is descriptive without translation of the author's main ideas. Elements such as scanning quickly, counting pages, not attaching importance to details and only focusing on main topics are signs of problematic learning styles. These students try to reduce the content, but not by chunking or making short cuts, but by simply cutting out information. Their answers on question 3 give the impression that they have no idea about the benefits of a scheme; we find words as content table, an abstract and some arrows. There is only one student (*x4*) who gives answers that are, in our opinion, valid and his scheme is an excellent example of a mind map. It contains the whole philosophy of the author's text. Despite this, his exam performances were extremely weak in almost all disciplines. This student admitted that his study method in secondary school was inappropriate and therefore he had taken some lessons to approve his study process. Mind maps help him in understanding the content.

On the basis of simple questions, differences are noted between *x*- and *y*-students. We realise that these preliminary conclusions are based on a small number of students (10). At first sight we would say that proficient (*y*)-students express their study approach in similar terms; *overview* and *structure* are terms that frequently appear. Students who use expressions such as *counting, reading and reading again, skipping tables*, etc, could be considered as weaker students.

(b) Chemical vocabulary test results (from the performance part)
The aim of the test is to emphasise a correct use of chemical vocabulary, which in its turn will increase the comprehensibility of schemes. Students' answers are shown in the Appendix. Our experience is that good students spontaneously use the appropriate chemical vocabulary while weaker students do not. When you tell them that one cannot speak French without actively studying its vocabulary and grammar, they all agree. When chemistry is at stake, many students do not go beyond the level of passive knowledge,[26] while assessment strongly emphasizes problem solving. Reciting definitions are part of it, but of minor importance.

The content of the test is short, basic and extracted directly from the text. Prior to the test, and after the text analysis discussion part, students were asked whether they still have some questions.

The test contains 4 questions:
1. Explain the meaning of a subscript.
2. Give two examples of a formula unit
3. Explain the term: *limiting reactant*
4. Explain the term: *stoichiometric ratio of reactants.*

Comparing the groups (*x*, *y* and *z* students) we found different kinds of responses. The subscript question was well answered, though some students talked about the number of atoms in a bond (*x7, x8* and *y5*). Many students illustrate question 1; the most popular molecule seems to be Cl_2. Students (*z1* and *x5*) give partially correct answers. Their illustrations are correct, but the written explanation for question 1 does not make proper use of basic chemical terminology, i.e. talking about "*atoms from an entity that form a molecule*". Probably they mean atoms from one particular element. *Y*- and *z1*-students (we have no answers from student *z2*) gave correct examples for question 2. Errors were only made by *x*-students: some of them gave the water molecule or some acids (HF and HCl) as examples of a formula unit, or made subscript errors, i.e. BaCl. The definition for question 3 is strictly given as: that reactant that is fully consumed when the reaction is complete. Only student *y6* discussed its role in a stoichiometric calculation: namely, the reactant that governs the maximum amount of product that can be formed. Many answers (*x3, x7, x8, x9, x10, y2, y5)* are limited to the reactant that is fully consumed in a chemical equation without referring to the presence of another reactant in excess. Students *z1* and *y4* explained that the limiting reactant causes the reaction to deplete, neglecting some thermodynamic principles. It is indeed possible that this misconception could appear, as many of our students were not taught about elementary thermodynamics in secondary school. Student *x4* used his own vocabulary: "*a reaction cannot go on forever; it has to come to an end*". Concerning question 4, the stoichiometric ratio of reactants was a largely unknown term to all of our students. We found the following answers: "*it is a ratio of coefficients*" (*x3, x5, x8, x10*), some specify this by reactants' and products' coefficients (*x3*), others added that this ratio must equal the smallest whole number (*x5, x10*). But none of them connected the stoichiometric ratio of reactants to the amount of moles that are formed and disappeared. It is remarkable that none of our *y*-students answered question 4, which made us assume that they preferred not to answer when they were not sure. *X*-students were more inclined to give answers, even when these questions were half correct or nonsensical. We were surprised to see such a variety in answers after the 30 minutes text analysis part.

(c) Scheme results (from the performance part)

We were interested to find information on the following questions in their schemes: a) what do students actually retain from the text discussion (not reported here) and b) how is their use of chemical terminology that was the subject of the test? For point b) students went through the whole text, by asking *what* is this paragraph about, *how* is it explained and *why* is this (chemical equation) useful. We advised them to recall the main ideas/concepts resulting from the discussion that is an answer on *what-why-how*, to use key-terms and to avoid full-sentences.

Because we knew that some students had never produced a scheme, we asked them not to start from the top because that would initiate a top-down linear representation, which might lead to an abstract instead of a scheme. The whole group was advised to look for one idea, that should exemplify the text and that could be used as an excellent starting point, placed in the middle of what would become their scheme. In our analysis we used the checklists given in Tables 1 and 2. The hierarchic levels are based on the instructor's expert scheme produced from the same text that students had to study. It was not our purpose to grade their schemes, because students were not trained in making schemes.

Many students chose as starting point a chemical equation, often illustrated by
$2Na\ (s) + Cl_2\ (g) \rightarrow 2\ NaCl(s)$ (I.1.1.).
At the descriptive level (I), we did not find many differences between student groups. Almost every student gave a complete definition of a chemical equation on the level of I.1.2. When a reaction equation was their central starting point, the example in their handbook was copied (I.1.1.1). They were not told to choose other examples (I.1.1.2.) than those given in the text. We were just interested to see whether *y*-students would look for other examples, which they didn't. Applications of stoichiometric calculations mentioned in the text; i.e. oxygen combustion reactions, redox and pH-calculations, which we categorised at the explanatory level (III.2.1), were not found in any of the answers, except for student *y7*. It means that the *why*-question in the explanatory level is not really one of their initial concerns. At this level, there is not much difference between *x*-, *y*- and *z*-students.

X-students do not explain what is meant by balancing a chemical equation (I.1.3.1), but do mention its interpretation at microscopic and macroscopic level (I.1.3.3.) without referring to the latter's practical use (IV.1). In the text analysis discussion, emphasis was first placed on the microscopic and then on the macroscopic interpretation. After that, the question was raised: *why* did the author mention these two levels? Despite the earlier discussion part, only *x4, x10* and *y2, y3, y6* students seemed to retain the microscopic and macroscopic interpretations of a chemical equation. *X4* was most clear in his explanation: the macroscopic interpretation of a chemical equation is for practical use.

A link between chemical equations and stoichiometric calculations was made by almost all students, though the calculation procedure (III.1.1) was in many cases not mentioned at all (*x5, x6, x8, x9, x10, y2, y5*) or only partially (*x3, x7, y3*). One (*x3)*-student recognized the aim of a stoichiometric calculation, namely the calculation of an expected yield, but the protocol and control mechanism, i.e. the law of mass (IV.2) is absent. The concept of stoichiometric ratio (IV.3) was, despite the earlier test and feedback, not found in any *x*- and *z*-scheme, except in that of student *x4*. We recall that in the chemical knowledge test (Appendix) *y*-students did not give an answer to the stoichiometric ratio question. Despite the blank answer, we notice that (perhaps due to the feedback) this term appeared in certain schemes (*y1, y3, y6, y7*). Later on, it turned out that these students were among the best of their year.

Although we realise that an expert scheme is probably more detailed than what any novice could produce, we think that certain distinctions can be drawn among students at the three characteristic levels. Almost all *x*-students kept their text representation at the descriptive and procedural level. What they call *important topics* are in most cases elements of description (see previous discussion in the *Results section: forethought*). The concepts (IV) are also largely absent.

Z-students who pass after their second resit were incomplete in their schemes. While their schemes were easy to follow, they were incomplete on the concept level. They paid much attention to procedures that would help them when problem solving calls for algorithmic procedures, but we cannot detect whether they made use of control mechanisms, such as the law of conservation of matter (IV.2) and checking for a limiting reactant (IV.4). The control aspect is one the most import self-regulation activities.

All *y*-students, who obtained a minimum score of 55% on their chemistry exam, had more complete schemes and the explanatory level is given in detail where concepts (IV.2, and IV.4) appeared on every *y*-scheme. They also differed from the other students by their choice of the topic placed in the centre of their scheme. Instead of the chemical equation (I.1.1.), they used the aim of the text: stoichiometric calculations (III.1). This term belongs to the explanatory level.

Discussion

To discover study styles that may be the source of problems for students taking the General Chemistry course, this IWG has to examine three activities. It has to look at their study plan (1) (forethoughts) which should reveal their general study skills, at their test results assessing their chemistry knowledge (2), and their ability to interpret text by means of a scheme (3). In their study plans one must look out for words or phrases that may indicate a surface approach to studying, such as: '*a quick read*', '*concentrating on just the important topics*', counting pages, and not paying much attention to details.

The way the 'how' questions are answered has to be examined as well (in the discussion part and its translation in their scheme). Is there any sign of mismatch between question and answer; does the scheme only include summary, headings and subheadings? Answers left blank, erroneous use of chemical terminology and nonsensical answers also need to be examined. When these are found, students need to be urged to practise self-assessment and reflect on their performance. Why do they not respond to the question if everything was clear after the discussion part; why do they write answers that are incorrect, what makes them feel they have everything under control? The chemical vocabulary tested and discussed should appear somewhere in their scheme.

In our analysis, we discovered that strong students immediately catch up with what they don't know or have forgotten. Weak students don't. For example, stoichiometric reaction ratio (question 4) is such a term that we did not find in any scheme made by *x*-students.

Some students did not hand in their answers to the test and study-plans questionnaire. This applies to the two *z*-coded students and some *y*-students. Some of these y-students obtained 80% scores for their chemistry exam. It would have been interesting to know their study plan and test results to see in what they differ from other students.

We have also identified some problems with this IWG approach. As the IWG outcome largely depends on the students' interaction, it is possible that there is no time available for the last part; namely the best student's scheme demonstration and its discussion. Individual feedback on shortcomings in study style has to be given then after the IWG session. With the aid of a checklist, this could be quickly provided. If the same students would enrol for a series of chemistry IWG-activities, both instructor and students could benefit more from the previous experience. For the IWG instructor, the use of schemes gives more insight into students' divergent use of thinking. Instruction methodology can thus be improved. Changes in study approaches could be studied as well when the same students follow the whole IWG series, but at this moment this is not the case. The problem of study load remains. When students also participate in other IWGs, we cannot force them to attend the chemistry IWGs. We can only hope that a certain transfer of skills happens.

If this IWG is used as a diagnostic tool, the message sent to weaker students may help them avoid premature drop out. The general goal for all IWG activities remains the training of general and domain-specific skills. In the subsequent IWG activities for chemistry, a scheme or mind map is again used as a tool for text analysis, but greater emphasis is placed on critical thinking.

Acknowledgements
The corresponding author is indebted to her colleague Eddy Carette of the Vrije Universiteit Brussel for his valuable suggestions. The author is also grateful to Dr. Drina Jaspers for her important practical contributions in the development of two IWGs.

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Appendix

Students' answers on the four test questions in the Performance part of the IWG-session.

STUDENT	MEANING OF A SUBSCRIPT	2 EXAMPLES OF A FORMULA UNIT	LIMITING REACTANT	STOICHIOMETRIC RATIO OF REACTANTS
z1	In Cl_2, the number 2 is called an index and explains how many atoms from an entity are to be found in a molecule.	KCl, NaI	The entity that causes a reaction to deplete because its quantity is smallest	The ratio of an element at the beginning and at the end of a reaction
z2	-	-	-	-
x3	In Cl_2, the number 2 is called and index and explains how many atoms are to be found in a molecule.	$BaCl_2$, KCl	It's a reactant that is fully consumed	The ratio of reactants' and products' coefficients
x4	It gives the total number of certain atoms in a molecule	HCl, HF	A reaction cannot go on forever, it has to come to an end.	There is an equal amount of atoms on both sides of the reaction equation
x5	It gives the number of certain atoms from a particular entity that appears in a molecule	BaCl, LiCl	It causes a particular reactant not to be consumed fully.	The ratio of coefficients needs to be as small as possible
x6	-	-	-	-
x7	Numbers (right under) that explain how many atoms form a compound, i.e. O_3: 3 atoms are bound.	KF	A reactant that is consumed	A ratio of numbers
x8	Number of bound atoms	KF, HF	A reactant that is consumed after the reaction is finished	A ratio of coefficients: i.e. 1:2:1.
x9	$FePO_4$: 4 is an index and represents the number of oxygen atoms	$BaCl_2$, $Ba(OH)_2$	The limiting reactant in a chemical reaction is an entity that is totally consumed.	-
x10	Indices are numbers that say how many atoms a molecule contains.	KBr, H_2O	Is an entity that is fully consumed in a reaction	It is a coefficients' ratio that must be as small as possible in a chemical reaction.
y1	-	-	-	-
y2	Number of atoms in a molecule	Diamond, graphite	Is an entity that is fully consumed in a reaction to get depleted	-
y3	-	-	-	-
y4	Cl_2, H_2O, number of specific atoms in a molecule	NaBr, KI	It is a reactant that is consumed and that finishes the reaction	-
y5	Whole numbers that explain how many times an atom appears in a chemical bound.	NaI, KI	Is an entity that is fully consumed in a reaction	-

y6	Number of specific atoms in a molecule	CsCl, KCl	A reactant that is fully consumed in a chemical reaction. It is also the reactant that governs the maximum amount of product that can be formed	-
y7	-	-	-	-