problems encountered in real-life situation. They may be simplified, so the students are able to solve them. During their research, where they will use the knowledge the students are acquiring, problems are often open ended. It will not be certain that a solution is correct. Problem solving is part of a larger process. This should become clear to students as well.

The level of the problems is an important issue. If they are too easy students will no longer be motivated to come to the tutorials. If they are too difficult they will get frustrated.

Students will not immediately be able to design a problem-solving strategy. They need to be trained to do so. A simple straightforward strategy that can be used to work any kind of problem is called the Systematic Problem-Solving Approach (Gok, 2015):

- It involves as a first step an analysis of the given variables, the relevant concepts and relationships, and the desired answers
- From this inventory, a strategy is designed to find the answer, using the given variables and the relevant theory. To construct the strategy, diagrams are often helpful to indicate relationships.
- Once the strategy is set, the answer is calculated or derived.
- Finally, a check is made to see if the answer is more or less logical.

If you want your students to adopt this approach you will need to demonstrate this approach explicitly every time when worked solutions to the problems are handed out or discussed with the students.

Finally, because students will normally work in a group when doing research, you can choose to let them work alone or in groups. When using the Systematic Problem-Solving Approach, it seems most logical to do the first two steps, as well as the last step together. The third step using the chosen strategy to work the problem is normally an individual process. Having students compare the results after they have done the derivation and calculation separately will also give some sort of indication about the accuracy of the solutions they have found.

3.4.1.5 Problems during the tutorial session

There are several possible issues that can occur during a tutorial. The first is attendance. You may make attendance a requirement of the course, but still the number of students attending the tutorial can drop. If that is the case with just one TA, he or she has a problem that needs to be solved. If it is the case for all tutorials most likely the students feel the tutorial has no added value. Either it is too easy or it is too difficult. If that is the case the remedy is obvious as well.

You can also get mixed reactions. Some students think the level is too high, others may find it too low. This is especially the case when the background of the students

is different. Often courses are open for students from say engineering and science, or for pharmacy and chemistry. This difference in background can lead to that type of reactions. You can solve such a problem by grouping the students according to their background. The requirements of the course will not change, but it is easier to pay attention to specific problems students may have.

3.5 Use of laboratory

3.5.1 Introduction

Chemistry is a science in which lab work often plays a dominant role. Most sciences actually involve a lot of practical work. It seems logical therefore to include practical work in science education, especially in the undergraduate study.

Practical work can differ enormously. It may vary from synthesis and analysis of a compound, to measurements and analysis of data. Students need to learn using instruments for spectroscopy, Gas Chromatography Mass Spectroscopy (GCMS) to name a few. In chemistry, they need to learn to use the available glassware and follow lab procedures.

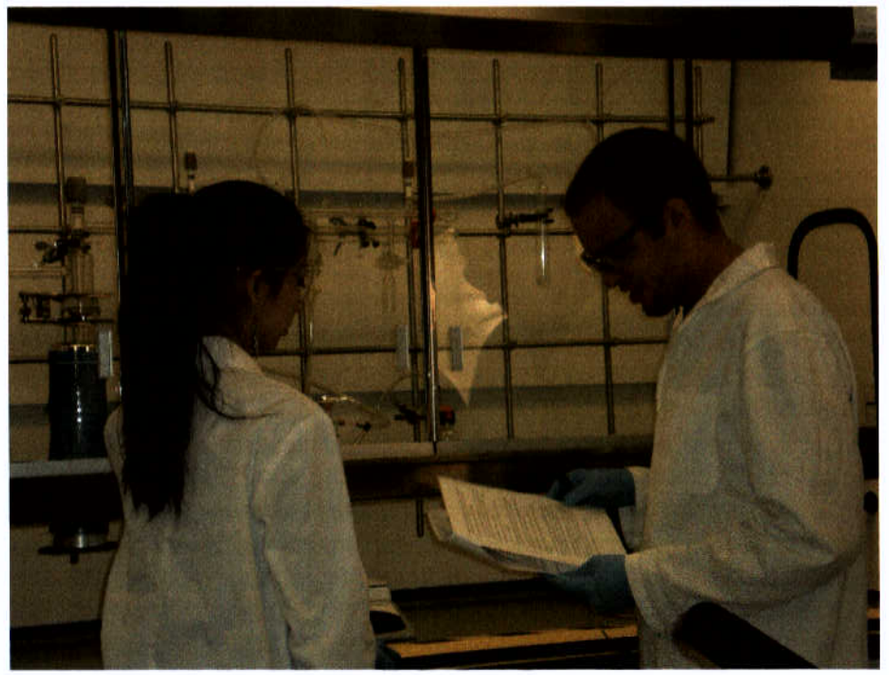

Figure 3.6: Working in a chemistry lab (source: Flickr).

3.5.2 Goals of practical work

For the use of practical work in education, several reasons can be formulated (Hofstein & Lunetta, 1982):

1. To arouse and maintain interest, attitude, satisfaction, open-mindedness and curiosity in science
2. To develop creative thinking and problem-solving ability
3. To promote aspects of scientific thinking and the scientific method (e.g. formulating hypotheses and making assumptions)
4. To develop conceptual understanding and intellectual ability
5. To develop practical abilities (e.g. designing and executing investigations, observations, recording data, and analysing and interpreting results)

Practical work offers a rich environment for learning. It needs careful planning in order to achieve these learning goals. Buck et al. (2008) have attempted to characterize practical work according to the goals it wants to achieve.

Table 3.5 lists an overview of the way inquiry in the undergraduate laboratory can be characterized.

Table 3.5: Characterization of level of inquiry in undergraduate laboratory (adapted from Buck et al. (2008).

Characteristic	Level 0: confirmation	Level ½: structured inquiry	Level 1: guided inquiry	Level 2: open inquiry	Level 3: authentic inquiry
Problem/question	Provided	Provided	Provided	Provided	Not provided
Theory/background	Provided	Provided	Provided	Provided	Not provided
Procedures/design	Provided	Provided	Provided	Not provided	Not provided
Result analysis	Provided	Provided	Not provided	Not provided	Not provided
Conclusions	Provided	Not provided	Not provided	Not provided	Not provided
More structure	←				Less structure

Several levels have been introduced based on the activities that students are expected to do.

These activities are based on the way research is conducted at university. Ultimately one of the goals is to educate students in such a way that they can do independent research within a group.

These activities can include the following:

- Students need to be able to formulate a research question or a problem they need to solve
- Students need to be able to familiarize themselves with the theory and the background

- Students need to be able to formulate a hypothesis or an expectancy of what they will find
- Students need to be able to formulate a procedure or design of an experiment they are to perform
- Students need to be able to gather the data/perform the experiment
- Students need to be able to analyse the results of the data they have gathered
- Students need to be able to communicate the results
- Students need to be able to relate their results to existent literature
- Students need to be able to draw conclusions from the experiment

Depending on the activities students actually do in a lab session, a lab assignment can be characterized as (see Table 3.5)

- confirmation;
- structured inquiry;
- guided inquiry;
- open inquiry; and
- authentic inquiry.

When laboratory experiments were analysed according to Table 3.5, out of 386 experiments only 26 were considered "guided inquiry" and only 5 were "open inquiry", even though students at the end of their bachelor are expected to have mastered level 3. Table 3.5 gives an opportunity to analyse a laboratory assignment (Buck et al., 2008).

From these data, it can be concluded that in most undergraduate labs, students only gather data, report on the data and draw the conclusion that the theory is correct (level 0 and ½ from Table 3.5). Because students realize they are just repeating experiments, they are not stimulated overmuch and often do not prepare well for a lab period. They are not really aware of what they are doing and are not very interested. They don't see the learning effect of the lab, and therefore are not very motivated. It is a chore to get through. Making a practical assignment more challenging is one of the ways to achieve more student interest. Besides it prepares them better for future lab periods, which is as important as making clear what you want your students to achieve and learn in the laboratory assignment.

There are plenty of examples in which the design of a lab activity can be changed to accommodate more goals. One example is a lab activity at the University of Chicago (Keller & Kendall, 2017). In the honors class of an organic synthesis lab the procedures were changed in such a way that the students were involved in a lot more activities than they were in the regular class.

They were expected to (Keller & Kendall, 2017):

- Search for and obtain literature articles
- Evaluate the literature for relevance
- Prepare an experiment based on published results

- Work within a group to accomplish a common goal
- Present results in a professional manner

This included deciding themselves which spectroscopic method was needed to determine the result of steps in the synthesis and deciding whether their intermediate was pure enough to continue with the next step.

It is not that difficult to adjust a lab exercise which contains more activity from the students. Consider the following example:

Most general chemistry courses introduce simple titration labs. Very often the complete procedures for this type of lab exercise are given. All the students have to do is to follow the exact steps given. Changing this procedure slightly gives students a lot more insight in the whole process. For titration, students need to familiarize themselves with the use of the volumetric glassware. This can be done in a regular lab session of maybe 3 hours, in which volumetric glassware is introduced. They need to practice at least with a pipette, a burette and a volumetric flask, apart from regular glassware such as beakers and Erlenmeyer flasks. They should also practice with a simple HCl/NaOH titration, so they are also familiar with procedures and observing an endpoint.

Assuming that in the theoretical lectures they have learned about endpoint pH, and calculations, you can then give them the assignment to bring vinegar into the lab for the next session and to determine the acetic acid concentration in the vinegar. They should write a work plan to do so themselves. After they have determined the concentration, have the group compare their results. Indicate that the results should not vary more than 1%. Then have the students discuss what could be improved in their procedure. Have them redo the experiment the next time, ensuring this time that results are within 1% of each other.

When you plan a lab session it is important to formulate the exact goals you wish to achieve. As mentioned above these goals may involve:

- Development of practical abilities
- Arouse interest, attitude, satisfaction, open-mindedness and curiosity
- Develop conceptual understanding and intellectual ability
- Promote aspects of scientific thinking and the scientific methodology
- Stimulate creative thinking and problem-solving ability

Equally important is that the students are aware of the learning goals you wish to achieve.

3.5.3 Actual planning of a practical activity

There are several bottlenecks for practical work:

- The number of laboratories
- The facilities like hoods, gas, electricity, air, vacuum in the rooms

- The glassware that can be used
- The measuring instruments available
- Computers and Information and Commuication Technology (ICT) available
- The number of lab assistants you may use
- Safety procedures in the lab

If you plan a lab activity you are the ultimate person responsible for the safety of the students and lab assistants working during the activity. That should be your first concern.

One of the factors in safety is the number of students per lab assistant. Even though this depends a bit on the type of activity of course, that should not be above 8 to 10.

Instruction about lab safety is an important factor in safety in the laboratory. Students should be very aware of safety measures. Not only self-protection measures like goggles, gloves and lab coat that should be used, but especially procedures in case of an emergency such as where to go, who should be notified and so on but also specifically what not to do and leave to others. Safety instruction should include the possibility that the TA responsible for the group is himself or herself incapacitated. Special precautions in the lab, like the use of a hood, not eating and drinking in the lab must be enforced. Special care must be taken for measures to prevent pollution of the environment, when disposing of waste materials, including chemicals, solutions and broken glassware.

You will need to prepare some sort of written instruction for the students.

3.5.4 Preparation

When planning the lab take into consideration what a student should do before he/she comes into the laboratory. Planning lab work is something students should learn. Part of planning should exist for familiarizing the students with the way the lab works; for example, learning where to find materials, how to obtain a spectrum, where to get the equipment to be used during the lab, how to set up and use the glassware, the measuring instruments and so on during the experiment. Students should by that time also be familiar with safety procedures. This will help them in formulating their work plan.

Part of the formative assessment of this part of a lab period could be a short video made by the student in which he or she demonstrates that he/she is able to use the glassware or instruments as they are supposed to be used. There are many examples, but include the ones like the use of a burette, a pipette or the use and safety in working under vacuum. Almost everyone has a mobile phone that can be used for making such a video.

By making this a prerequisite for the actual experiments you want them to perform you stimulate the students to pay much more attention to this part. It will enhance the results of the actual experiments.

There should be a sufficient time lap between this introductory part of the lab and the actual experiment you want the students to perform. They need to think about what they learned, so they can actually use their experience in their proposed work plan.

Students should formulate a work plan before they start their lab work. Such a work plan should include some remarks about lab safety.

A work plan can also include some preliminary experiments students might want to perform before they can finalize their work plan.

In the work plan some of the goals you wish to achieve with the practical activity can be assessed. Important aspects like

- students need to be able to familiarize themselves with the theory and the background;
- students need to be able to formulate a research question or a problem they need to solve;
- students need to be able to formulate a hypothesis or an expectancy of what they will find; and
- students need to be able to formulate a procedure or design of an experiment they are to perform

can be assessed in the work plan.

Have the students come in before the day the lab is planned and let them check their lab work plan with a TA. Or you can have them submit it in electronically. They should get feedback and not be able to start their work without formal clearance by you or the TA.

This type of preparation gives you and the people assisting in the lab session enough time to assemble all the instrumentation and glassware needed for the actual experiments. One of the most often heard comments is that staff has no control over the experiments when they are planned so open. Giving enough time for assembling the material will show that this is not a real problem.

3.5.5 Performing the experiment

Plan enough time for students to perform the experiment. If you want to assess their practical abilities during the experiment, make sure you have an adequate protocol both for the assessor and the assessed students. They should be made aware what they are being assessed on, especially if it is a type of summative assessment.

Make sure the students gather enough and accurate data, and stimulate them to take photographs or sketches of their set-up.

3.5.6 Reporting

Reports are needed to assess the following goals:

- Students need to be able to analyse the results of the data they have gathered
- Students need to be able to communicate the results
- Students need to be able to relate their results to existent literature
- Students need to be able to draw conclusions from the experiment

Requirements for the report should be formulated in such a way that the relevant learning goals can be assessed.

Reports can be made in several ways. You may require a written report, following a certain format. Several possibilities exist. In early courses, pre-printed formats are often used. In later courses, the format of articles may be used.

In order to exchange information between students, posters or PowerPoint presentations can also play a role. Basically, students need to learn how scientific results are communicated. Posters, oral presentations and articles are the predominant form in which this happens. It seems logical to use these in the training phase as well.

3.5.7 Affective domain

The lab work is often seen as one of the attractive aspects of studying science and chemistry in particular. It gives some insight in the type of work the students will be doing in later stages.
These goals in the affective domain stimulating

- interest,
- attitude,
- curiosity and
- open-mindedness

are often not explicitly formulated. In the assessments described, affective goals are not measured. It is important for the design of the whole lab activity to do this however. You can make this part of the evaluation of the whole lab activity.

There are several ways to assess these goals and to evaluate. You can use a questionnaire that is presented to the students, or you can interview some of them in which you query them on these aspects. This could also be done when you or the TAs discuss a student's report with a student after it has been graded.

3.5.8 Evaluation

As all educational activities, you should evaluate this particular activity as well. Based on the work plan and the reports you can get some indication whether you reached

the learning goals. A discussion with the TAs is part of the evaluation. For yourself as well as for the TAs it is important that the students rate them. This can be part of the questionnaire used to assess the affective domain.

3.6 Mentoring group work

3.6.1 Introduction

There are several types of groups that you may be asked to mentor. First year students often have problems adapting to the change between secondary school and university (Chaplin, 2007). In other cases, you may be asked to guide students engaging in some group assignment. Students need to learn how to work and function in a group. During their professional career, they will normally be part of a team, with their own responsibilities. They need to learn how to function in a group. Apart from that, skills training and cognitive training will also be part of the group work.

3.6.2 Role

The role you have in leading group work is that you are more a coach than a teacher. Instead of being a source of information you are now there to guide the process going on in the group. Basically, your role is the same as a sports coach. The subject is different, however. You are not focusing on athletic abilities and skills, but on learning skills. Your main goal is to improve the learning skills of the students by showing them how to gather information, how to process the information directed to the assignment the group has to fulfil.

When you are coaching a first-year group, focus will be on general study skills such as critical reading, time management and self-directed learning. You will be amazed how much difficulty some students may have in adapting from high school to college (Chaplin, 2007). Helping the students "how to learn" is the main focus of these groups. They often have poor time management, are not very skilled in note taking and don't listen very well. Very often some guidance will help them on their way and adapt to this new situation.

3.6.3 Supervision groups

There are several aspects you need to be aware of in supervision of students.

You need to be aware of the task you have regarding a group of students. You act as coach, teacher, critic and judge. You also have a task in the summative assessment

of the student. This double role can create some problems. You will need to decide how you build up a relationship with the students.

- Will you keep it business like or personal?
- Do they address you as professor, or do they use your first name?
- How intensive is your supervision? Will it be very close, students need to report to you in short time intervals, or is it distant, students report only after major steps have been taken?
- What is the orientation of your supervision? Is it product oriented or is it focused on the process?
- How well prepared are the students? How are their writing skills for example?
- How can students be coached into a certain direction?
- What do you expect from your students?
- What are you responsible for?

Answering these questions and discussing them beforehand with the group of students will make your role as a supervisor much more easy and effective.

3.6.4 Approaches

As a coach in such groups you can choose different approaches depending on the ability of the group (Glickman & Gordon, n.d.):

- You can take a nondirective approach, when the students are clearly able to find their own way and take initiative. The students collaborate and have equal input.
- An informal directive approach for groups who have problems finding a way to cope and start with their assignment. You can provide them with several options from which they choose one. After that the students collaborate.
- A directive approach for students at a lower level, where you take the responsibility for the type of action to be taken. You divide tasks and make sure everybody has enough input.

3.6.5 Feedback

Normally the group work will be part of a course in which you have the role of mentor/coach of the group. You will be asked to give feedback to the results of the group work regularly.

There are several types of feedback that can be asked as is indicated in Table 3.6. There are different types of comment, as is indicated in Table 3.7.

Both for the feedback you receive and the feedback you give to students these indications are important. The types are easily recognizable. The type of feedback you give depends on the phase of the work. There are three phases in group work: