# PERFORMANCE ASSESSMENT OF PRACTICAL SKILLS IN SCIENCE IN TEACHER TRAINING PROGRAMS USEFUL IN SCHOOL

*Ann Mutvei and Jan-Eric Mattsson*
School of Natural Sciences, Technology and Environmental Studies, Södertörn University, Sweden.

*Abstract:* There is a general process towards an understanding of knowledge not as a question of remembering facts but to achieve the skill to use what is learnt under different circumstances. According to this, knowledge should be useful at different occasions also outside school. This process may also be identified in the development of new tests performed in order to assess knowledge.

In courses in biology, chemistry and physics focused on didactics we have developed performance assessments aimed at assessing the understanding of general scientific principles by simple practical investigations. Although, designed to assess whether specific goals are attained, we discovered how small alterations of performance assessments promoted the development of didactic skills. Performance assessments may act as tools for the academic teacher, school teacher and for enhancement of student understanding of the theory.

This workshop was focused on performance assessments of the ability to present skills and to develop new ideas. We presented, discussed, explained and familiarized a practical approach to performance assessments in science education together with the other participants. The emphasis was to demonstrate and to give experience of this assessment tool.

We performed elaborative tasks as they may be used by teachers working at different levels, assessed the performances and evaluated the learning outcome of the activity. Different assessment rubrics where be presented and tested at the workshop. Learning by doing filled the major part of the workshop but there were also opportunities for discussions, sharing ideas and suggestions for further development.

The activities performed may be seen as models possible for further development into new assessments.

*Keywords:* assessment, rubric, practical skills, knowledge requirement

## INTRODUCTION

During the last ten or fifteen years there has been a general process towards an understanding of knowledge not as a question of remembering facts but to achieve the skill to use what is learnt under different more or less practical circumstances. According to this view knowledge should be useful at different occasions also outside school. Traditional textbooks often had facts arranged in a linear and in a hierarchical order. More recent books are focused on the development of the thoughts and ideas of the student by presenting general principles underpinned by good examples, diagnoses, questions to discuss, reflective tasks without any presentation of a correct answers, etc. (cf. Audesirk et al. 2008, Hewitt et al. 2008, Reece et. al 2011, Trefil & Hazen 2010). A similar development can be found in teacher training programs, where lectures and traditional text seminars to some extent have been replaced by more interactive forms of teaching. This development we also found in examinations at our own university where tests performed in order to assess knowledge of literature content have been replaced by tests where students have to show their capacity to use their knowledge.

Practical performance assessments are important when assessing abilities or skills of students in teacher training programs. In science courses in biology, chemistry and physics focused on didactics we have for several years developed performance assessments focused on understanding of general scientific principles, but based on simple practical investigations or studies. Although, designed to assess whether students reached the goals of a specific course, we often have discovered how small alterations of these performance assessments have promoted the development of the didactic skills of the student. Thus, they may act as assessment tools for the academic teacher, models for assessments in school and enhancement of the student's theoretical understanding of the subject and theory. The assessments may be made on oral or written reports, during guided excursions or museum visits or practical experiments, on traditional or esthetical diaries, self diagnoses or diagnoses made by other students based on certain criteria.

We have been working several years with teacher training programs focused on work in primary and secondary schools, with further education for teachers and with university students studying biology and chemistry. The wide range of courses and students have been giving us experiences how to work with different contents adapted to different ages of students at school. Out of this we have found some similar and different basic problems and needs of understanding depending on the subject. These experiences also give us the opportunity to contribute to national seminars and conferences.

## CURRICULUM AT SWEDISH SCHOOL

The new curriculum in Sweden for the primary and lower secondary schools (Skolverket 2010) as well as the new one for the upper secondary school put the emphasis on the student's skills rather than knowledge (facts). It is the ability to use the knowledge that is to be assessed. This development is a global trend; see e.g. Eurasian Journal of Mathematics, Science & Technology Education 8(1). This is a great change compared to earlier curricula, especially when compared to the common interpretation and implementation of these at the local level. A similar development has occurred in the universities in Sweden. Today the intended learning outcomes should be described in the syllabi as abilities the student can show after finishing the course and how this should be done.

Many teachers have problems with this view as they are used to assess the student's ability to reproduce facts. These teachers find it hard to understand how to work with performance assessments instead of tests targeting the knowledge of facts. They often ask for clear directions and expect strict answers instead of guidelines how to improve their own ability to work with performance assessments.

Teaching according to these new curricula starts with the design of performance assessments suitable for the assessment of a specific skill and to create a rubric for the assessment. Thereafter the teacher plans the exercises beneficial for student development and finally decides the time needed and plans the activities according to this.

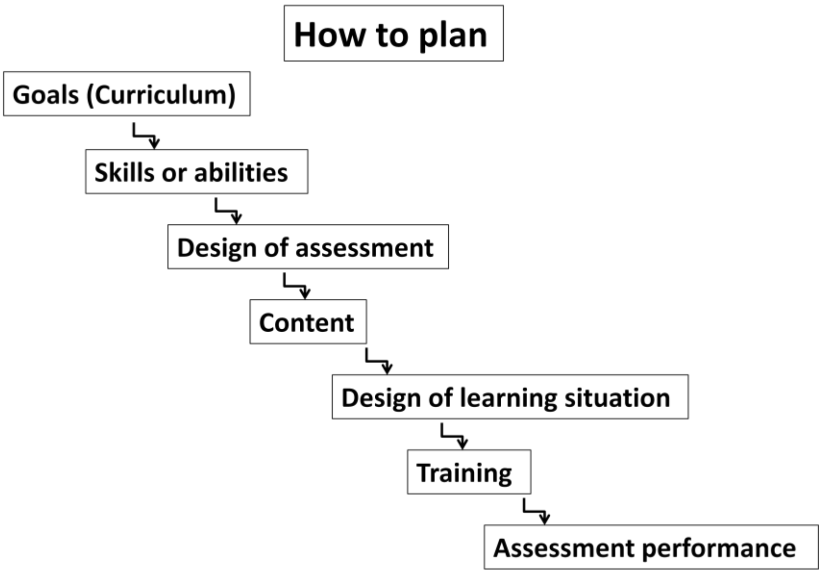


*Figure 1.* How to plan learning situations.

As an example of how teachers may work with this method we designed a practical assessment of practical skills and presented it as a workshop at ESERA 2013.

## HOW TO DESIGN A PERFORMANCE ASSESSMENT OF PRACTICAL SCIENCE SKILLS

In order to design a workshop on performance assessments of the skills we tried to do as teachers are supposed to do at school. The emphasis was to demonstrate and give a possibility to get experience of this assessment tool under realistic conditions. Thus, these performance assessments are constructed in accordance with the curriculum in Sweden from 2011 (Skolverket 2010) but they are probably useful for anyone who wants to assess abilities or skills rather than memories of facts or texts. We tried to present, explain and familiarize the participants with a practical approach to performance assessments in science education at school.

The skill of assessment has to be learned. If teachers are used to assess skills these normally are of a more or less theoretical kind. They are used to assess the quality of the language used or the correctness of a mathematical calculation. Assessment of practical skills does not has to be more complicated but it has to be trained. According to the Swedish curriculum 150–200 assessments of each student and in each of the about 15 school subjects should be done at the end of years 6 and 9 and many of these refer to practical skills. In order to simplify this monstrous task it is possible and necessary to assess several skills in more than one subject at one occasion.

We had prepared four similar activities, all with the same material; candle, wick, and matchbox but with different purposes. They were supposed to represent studies of mass transfer, energy transformation, technical design, and phase changes. The latter is presented here in detail.

## General principles of performance assessments

In the preparations we followed the directions of the Swedish curriculum for the compulsory school (Skolverket 2010). We selected the core content and the knowledge requirements relevant for phase transitions as the foundation for development of the performance assessment. Usually teachers start with the knowledge requirements, interpret these and design tests for assessing the students' skills according to the requirements, design suitable learning situations or practical training of the skills and finally decide what parts of the core content should be used (Figure 1). Here we started with the core content as it were some specific areas of knowledge we wanted to study. When the core content was selected the assessment rubric was developed by interpreting and dissecting the knowledge requirements.

### Core content

The teaching in science studies should, in this case, according to the curriculum of primary and secondary school (Skolverket 2010), deal with the core content presented in Table 1.

Table 1

*Core content in Swedish compulsory school curriculum relevant for phase transitions and scientific studies.*

| In years 1–3 | In years 4–6 | In years 7–9 |
|---|---|---|
| • Various forms of water: solids, liquids and gases. Transition between the forms: evaporation, boiling, condensation, melting and solidification. | • Simple particle model to describe and explain the structure, recycling and indestructibility of matter. Movements of particles as an explanation for transitions between solids, liquids and gases. | • Particle models to describe and explain the properties of phases, phase transitions and distribution processes for matter in air, water and the ground. |
| • Simple scientific studies. | • Simple systematic studies. Planning, execution and evaluation. | • Systematic studies. Formulating simple questions, planning, execution and evaluation. |
| | | • The relationship between chemical experiments and the development of concepts, models and theories. |

## Knowledge requirements

The knowledge requirements are related to the age of the students and show a clear progression through school. At the end of the third, sixth and ninth year there are clearly defined knowledge requirements (Table 2). Grades are introduced in the sixth year and levels for grades E (lowest), C, and A (highest) are described in the curriculum. Also D and B are being used. Grades D or B means that the knowledge requirements for grade E or C and most of C or A are satisfied respectively.

Table 2

*Knowledge requirements for different years and grades*

| | | | |
|---|---|---|---|
| Year 3 | Based on clear instructions, pupils can carry out […] simple studies dealing with nature and people, power and motion, and also water and air. | | |
| | Grade E | Grade C | Grade A |
| Year 6 | Pupils can talk about and discuss simple questions concerning energy. Pupils can carry out simple studies based on given plans and also **contribute to formulating** simple questions and planning which can be systematically developed. In their work, pupils use equipment in a safe and **basically functional** way. Pupils can […] **contribute to making proposals** that can improve the study. | Pupils can talk about and discuss simple questions concerning energy. Pupils can carry out simple studies based on given plans and also **formulate** simple questions and planning which **after some reworking** can be systematically developed. In their work, pupils use equipment in a safe and **appropriate** way. Pupils can […] **make proposals** which **after some reworking** can improve the study. | Pupils can talk about and discuss simple questions concerning energy. Pupils can carry out simple studies based on given plans and also **formulate** simple questions and planning which after some reworking can be systematically developed. In their work, pupils use equipment in a safe, **appropriate and effective** way. Pupils can […] **make proposals** which can improve the study. |
| Year 9 | Pupils can talk about and discuss questions concerning energy. Pupils can carry out studies based on given plans and also **contribute to formulating** simple questions and planning which can be systematically developed. In their studies, pupils use equipment in a safe and **basically functional** way. Pupils apply **simple** reasoning about the plausibility of their results and **contribute to making proposals** on how the studies can be improved. Pupils have **basic** knowledge of energy, matter, […] and show this by **giving examples and** describing these with **some** use of the concepts, models and theories. | Pupils can talk about and discuss questions concerning energy. Pupils can carry out studies based on given plans and also **formulate** simple questions and planning which **after some reworking** can be systematically developed. In their studies, pupils use equipment in a safe and **appropriate** way. Pupils apply **developed** reasoning about the plausibility of their results and **make proposals** on how the studies can be improved. Pupils have **good** knowledge of energy, matter, […] and show this by **explaining** and **showing relationships** with **relatively good** use of the concepts, models and theories. | Pupils can talk about and discuss questions concerning energy. Pupils can carry out studies based on given plans and also **formulate** simple questions and planning that can be systematically developed. In their investigations, pupils use equipment in a safe, **appropriate and effective** way. Pupils apply **well developed** reasoning concerning the plausibility of their results **in relation to possible sources of error** and **make proposals** on how the studies can be improved **and identify new questions for further study.** Pupils have very good knowledge of energy, matter, […] and show this by **explaining** and **showing relationships** between them and **some general characteristics** with **good use** of the concepts, models and theories |

## Assessments of knowledge requirements

The knowledge requirements were interpreted and dissected in smaller units in order to construct an assessment rubric adapted to the inquiry. Five main skills were selected from the knowledge requirements; *Use of theory*, *Improvement of the experiment*, *Explanations*, *Relate*, and *Discuss*. In order to make the assessment rubric more generalized we decided not to use the grades of the curriculum but recognized three levels of skills; *Sufficient*, *Good*, and *Better* corresponding to the grades E, C and A respectively. In all cases we also gave examples of relevant student answers. This is a more or less necessary requirement in order to make sure that the performer, assessor or teacher really understands what is meant by a specific requirement (Arter & McTighe 2001, Jönsson 2011).

As an example of this we can look at the knowledge requirement "Pupils can carry out studies based on given plans and also **contribute to formulating** simple questions and planning which can be systematically developed. In their studies, pupils use equipment in a safe and **basically functional** way. Pupils apply **simple** reasoning about the plausibility of their results and **contribute to making proposals** on how the studies can be improved." (Year 9, level E). This requirement contains information that may be dissected into several units.

Primarily it is necessary to look at the five skills of the students that are going to be assessed and look at the suitable requirements for each skill. The students are supposed to "carry out studies based on given plans". In the case the experiment is very simple, (light and observe a burning candle), and hardly useful assessing this specific skill. They shall "also **contribute to formulating** simple questions and planning which can be systematically developed". This requirement can be further developed to suit the five skills.

In order to show this skill it is necessary to have some knowledge about the theory and use it in a suitable way. The skill ”use of theory" is a necessary condition for this and may be formulated as "The student draws simple conclusions partly related to chemical models and theories." This criterion also is in concordance with the skill "**simple** reasoning about the plausibility of their results and **contribute to making proposals** on how the studies can be improved." This may be formulated as "the student discusses the observations and contributes with suggestions of improvements" in the rubric for assessment of the *improvement of the experiment* requirement.

In a similar way the assessment of remaining three skills may be developed into more specific criteria adapted to this experiment (Table 3).

In order to make it possible for the student to understand what is expected it is necessary to clarify the requirement criteria and give realistic examples of these requirements. The meaning of words differs between disciplines not only in the academic world but also in school (cf. Chanock 2000). This has consequences when students get feedback as they often do not understand the academic discourse with its specific concepts and fail to use the feedback later (Lea & Street 2006). Criteria combined with explicit examples are necessary to solve this problem (Sadler 1987). This is also important when designing assessment rubrics (Busching 1998, Arter & McTighe 2001). Thus, to every criterion there has to be at least one example given. In Table 3 this is exemplified in every combination of skill and grade requirement.

Table 3

*Assessment rubric for assessing skills in an experiment of phase changes*

| | Sufficient | Good | Better |
|---|---|---|---|
| Use of theory | The student draws simple conclusions partly related to chemical models and theories. (*I can see stearic acid in solid, liquid and gas phase*.) | The student draws conclusions based on chemical models and theories. (*The heat of the candle causes the phase transfer between the phases*.) | The student draws well founded conclusions out of chemical models and theories. (*Stearic acid must in gas phase and mix with oxygen to burn*.) |
| Improvement of the experiment | The student discusses the observations and contributes with suggestions of improvements. (*Observe more burning candles*.) | The student discusses different interpretations of the observations and suggests improvements. (*Remove the wick and relight the candle*.) | The student discusses well founded interpretations of the observations, if they are reasonable, and suggests based on these improvements which allow enquiries of new questions. (*Heat a small amount of stearic acid and try to light the gas phase above*.) |
| Explanations | The student gives simple and relatively well founded explanations. (*The stearic acid melts by heat produced by the flame*.) | The student gives developed and well founded explanations. (*Also the change from liquid phase to gaseous phase depends on the heat from the flame*.) | The student presents theoretically developed and well founded explanations. (*All phase changes from solid to liquid or liquid to gaseous need energy*.) |
| Relate | The student gives examples of similar processes as in the experiment related to questions about energy, environment, health and society. (*The warmth of the sun melts the ice on the lake at the end of the winter*.) | The student generalizes and describes the occurrence of similar phenomena as in the experiment related to questions about energy, environment, health and society. (*In the frying pan it is hot enough for butter to melt and in the sauna water vaporizes*.) | The student discusses the occurrence of the phenomena observed in everyday life and the use of it and its impact on environment, health and society. (*The phase change from liquid to gaseous phase cools you down when you are sweating*.) |
| Discuss | The student contributes to a discussion of the occurrence of the phenomena studied in society and makes statements partly based on facts and describes some possible consequences. (*Gases are often transported in a liquid phase which has a lower volume*.) | The student describes and discusses the occurrence of the phenomena studied in society and makes statements based on facts and fairly complicated physical relations and theories. (*The bottle of a gas stove has fuel mainly in liquid phase but it is transported in the hose and burnt i gaseous phase*.) | The student uses the experiment as a model and discusses the occurrence of the phenomena studied in society and makes statements and consequences based on facts and complicated physical relations and theories (*The phase change from liquid to gaseous phase cools you down when you are sweating*.) |

## WORKSHOP

We had prepared four similar activities, all with the same material; candle, wick, and matchbox but with different purposes. The activities represented studies of mass transfer, energy transformation, technical design, and phase changes. At the workshop three groups were formed, omitting the study of technical design. The three groups were not informed about the differences between the aims of their experiments. The groups were constructed to include people with as varied background as possible. Thus, participants from one specific country or similar fields as chemistry or physics were allocated to different groups. They performed elaborative tasks similar to those used by teachers working at different levels, assessed the performance and evaluated the learning outcome of the activity. Within each group one person was selected to do the assessment of activities the others made. The person assessing the work should focus not only on the results of the discussions within the group but also try to evaluate the process, as the aim was to assess the skills of the participants rather than the content of their knowledge.

*Discussion*

The aim was to demonstrate of how peer reviewing within the group may be used for producing information of several kinds beneficial for the performance assessment of science education at school. Discussions arose among the participants about how an integrated approach, especially in relation to other subjects in school, improved the usefulness of the methods. Learning by doing followed by discussions became the major part of the workshop with sharing of ideas and suggestions for further development.

Most of the participants had weak knowledge of assessments of practical skills and expressed their astonishment of the positive result of the workshop and showed curiosity to use the method. Some of the participants also showed didactic skills when explaining the different aspects of the experiment they mastered to the others, a good example of the importance of variation in the skills of group members.

The persons who made the assessments expressed the need of further practicing. They realized the complexity in assessing different skills at the same time as assessing the grade. They also expressed a will to develop this ability as they realized the strength in assessing several skills at one occasion. Further, the participants noted the importance of questions like the last on in the instructions (Appendix) in order to assess the quality of the relation between theory and practice.

*Conclusion*

Although, based on a simple experiment of a burning candle, the workshop gave a opportunity to discuss and understand theories being regarded as difficult to understand from the viewpoint of the student or difficult to teach from the teachers' view. The experiments, although similar, were of different character, thus, reflecting a wide spectrum of possibilities.

Thus, the activities performed may be seen as models or examples possible to further develop new assessments according to the content of the subject.

## REFERENCES


Arter, J. A. & McTighe, J. (2001). *Scoring rubrics in the classroom*, Corwin

Audesirk, T., Audesirk, G., & Byers, G B. (2008). *Life on earth*, 5 ed., San Francisco, Pearson Education.

Busching, B. (1998). Grading Inquiry Projects. *New Directions for Teaching and Learning 74*: 89–96.

Chanock, K. (2000). Comments on Essays: do students understand what tutors write? *Teaching in Higher Education 5* (1): 95–105.

Hewitt, P. G., Suchocki, J. & Hewitt, L. A. (2008). *Conceptual physical science*, 4 ed. San Francisco, Pearson Education.

Jönsson, A. (2011). *Lärande bedömning*. Gleerups.

Lea, M.R. & Street B.V. (2006). The "Academic Literacies" Model: Theory and Applications. *Theory into Practice, 45*(4): 368–377.

Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V. & Jackson, R. B. (2011). *Campbell Biology Global* Edition, Pearson.

Sadler, D.R. (1987). Specifying and Promulgating Achievement Standards. *Oxford Review of Education 13*(2): 191–209.

Skolverket (Swedish National Agency for Education). (2010) *Curriculum for the compulsory school, preschool class and the recreation centre 2011*. Skolverket.

Trefil, J. & Hazen R.M. (2010). Sciences an integrated approach. *Wiley Eurasian Journal of Mathematics, Science & Technology Education 8*(1).

## APPENDIX

### INQUIRY OF A BURNING CANDLE

This is an experiment of phase changes

1. Light the candle and observe the change of phases.
2. Which changes of phase can you observe?
3. Where do they occur?
4. Why do they occur?
5. What happens in the different phases?
6. How may you improve the experiment?
7. Give examples of phase changes in daily life and the society.

### INQUIRY OF A BURNING CANDLE

This is an experiment of energy transformation

1. Light the candle and observe the energy transformations.
2. Which changes of energy forms can you observe?
3. Where do they occur?
4. Why do they occur?
5. What happens during the different energy transformations?
6. How may you improve the experiment?
7. Give examples of energy transformations in daily life and the society.

### INQUIRY OF A BURNING CANDLE

This is an experiment of mass transfer

1. Light the candle and observe mass transfer
2. Which types of mass transfer can you observe?
3. Where do they occur?
4. Why do they occur?
5. What happens to the candle due to this mass transfer?
6. How may you improve the experiment?
7. Give examples of mass transfer in daily life and the society.

### INQUIRY OF A BURNING CANDLE

This is an experiment of candle design

1. Light the candle and discuss the design of the candle.
2. Which different parts can you observe in the candle?
3. Where are they and how are they united?
4. What function do the different parts have?
5. Why is the candle created in that way?
6. How may you improve the experiment?
7. Give examples of similar designs in daily life and the society.